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SERIES K: PROTECTION AGAINST INTERFERENCE

Protection of persons inside a structure using telecommunication services provided by metallic conductors against lightning – Risk management

Recommendation ITU-T K.89

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Summary

Recommendation ITU-T K.89 gives the methodology for evaluating the need to protect users of telecommunication equipment in structures and that of building occupants related to the telecommunication installation.

This method is based on a risk assessment: protection measures are necessary when the risk is greater than the tolerable risk. A maximum value of the tolerable risk is suggested.

The risk is evaluated using the lightning risk components which can be a source of injury to telecommunication service users and building occupants (lightning flashes direct to the line or to the structures connected at the ends of the line).

The risk assessment is done according to Edition 2 of IEC 62305-2. A simple risk assessment is provided to enable the telecommunication network operator to decide when to install gas discharge tubes (GDTs) at the point of entry of the telecommunication line into the structure independent of the structure attributes. This Recommendation can be used together with Recommendation ITU-T K.47, which provides a more accurate risk assessment of lightning flashes directly to the telecommunication line, and IEC 62305-2, which provides the risk assessment of lightning flashes to the structure.

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T K.89	2012-05-29	5

Keywords

Lightning, node, protection, risk, risk assessment, surge, SPD, telecommunication line.

FOREWORD

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Introduction

Lightning flashes to earth may be hazardous to the telecommunication network, the structures at each end of the line and the telecommunication service users.

The hazard can result in:

– injury of people inside the structures connected to the telecommunication line;
– physical damage (e.g., cable destruction) to the telecommunication line or structures;
– failure (e.g., insulation breakdown) of the telecommunication line;
– failure of the associated electrical and electronic equipment inside the structure (i.e., exchange, customer's building, or remote electronic site).

To reduce the loss (due to electric shock, physical injury or failure of internal systems) as a result of lightning flashes, protection measures may be required. Whether they are needed, and to what extent, will be determined by the risk assessment.

The risk, defined in this Recommendation as the probable average annual loss due to injury as the result of lightning flashes, depends on:

– the annual number of lightning flashes influencing the structure;
– the probability of damage by one of the influencing lightning flashes;
– the mean amount of consequential loss.

Lightning flashes influencing the structure may be divided into:

– flashes direct to a structure connected to the telecommunication line;
– flashes terminating on the telecommunication line entering the structure;
– flashes terminating near the telecommunication line;
– flashes terminating near the structure.

Flashes direct to a telecommunication line or a structure connected to the telecommunication line may cause physical damage to the structure and the telecommunication line. More importantly, they may cause injury to telecommunication equipment users, cause a fire in the premises or damage equipment, which could immediately endanger life. Flashes near the telecommunication line or the structure may also cause failure of the telecommunication line and of electrical and electronic systems inside the structures.

The number of lightning flashes influencing the structure depends on the dimensions and the characteristics of the telecommunication network, the characteristics of the structure, on the environment characteristics, as well as on lightning ground flash density in the region where the structure is located.

The probability of lightning damage depends on the telecommunication network, on the structure, on the lightning current characteristics, as well as on the type and efficiency of applied protection measures.

The annual mean amount of the consequential loss depends on the extent of damage and the consequential effects which may occur as result of a lightning flash.

The use of protection will reduce the probability of damage and the amount of consequential loss.

The assessment of risk due to all possible effects of lightning flashes, to the telecommunication network and the structure, are given in this Recommendation.

The decision to provide lightning protection may be taken regardless of the outcome of any risk assessment where there is a desire that there be no avoidable risk.

The boundary between IEC 62305-2 and ITU-T K.89 is that the former deals with the full risk assessment whereas the latter deals with the limitation of dangerous events at the structure from the telecommunication line. The telecommunication network operator can contribute to the customer's protection costs by limiting the number of dangerous events arriving at the customer's structure from the telecommunication line.

Recommendation ITU-T K.89

Protection of persons inside a structure using telecommunication services provided by metallic conductors against lightning – Risk management

1 Scope

This Recommendation deals with the risk management of lightning protection for occupants of a structure related to a telecommunication service using metallic conductor cables. Where the telecommunication service is provided by CDMA WLL, or similar, refer to [ITU-T K.71].

The risk assessment is limited to injury of occupants where the installation of the telecommunication service increases the risk of injury due to lightning. This Recommendation provides a procedure for the evaluation of such a risk. Once an upper tolerable limit for the risk has been selected, this procedure allows the selection of appropriate protection measures to be adopted to reduce the risk to a level at or below the tolerable limit.

This Recommendation is mainly aimed at mitigating the risk associated with a telecommunication service in a private, public or commercial structure. The risks in telecommunication structures are generally mitigated by network operator practices and policies. However, this Recommendation can be used for telecommunication structures if agreed by the telecommunication operator.

This Recommendation shall be used together with [ITU-T K.72], which provides the risk assessment against lightning flashes to the telecommunication line. Recommendation [ITU-T K.85] provides the risk assessment against equipment damage in customer premises.

The protection need for line equipment (such as multiplexers, power amplifiers, optical network units) and line termination equipment is not considered in 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 electronic site).

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.21] Recommendation ITU-T K.21 (2011), *Resistibility of telecommunication equipment installed in customer premises to overvoltages and overcurrents*.

[ITU-T K.60] Recommendation ITU-T K.60 (2008), *Emission levels and test methods for wireline telecommunication networks to minimize electromagnetic disturbance of radio services*.

[ITU-T K.66] Recommendation ITU-T K.66 (2011), *Protection of customer premises from overvoltages*.

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

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

[ITU-T K.85] Recommendation ITU-T K.85 (2011), *Requirements for the mitigation of lightning effects on home networks installed in customer premises*.

[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>

[IEC 62305-3] IEC 62305-3 (2010), *Protection against lightning – Part 3: Physical damage to structures and life hazard.*
<http://webstore.iec.ch/webstore/webstore.nsf/ArtNum_PK/46595?OpenDocument>

[IEC 62305-4] IEC 62305-4 (2010), *Protection against lightning – Part 4: Electrical and electronic systems within structures.*
<http://webstore.iec.ch/webstore/webstore.nsf/ArtNum_PK/46590?OpenDocument>

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following term defined elsewhere:

3.1.1 telecommunication network [ITU-T K.60]: Entirety of equipment (comprising any combination of the following: network cable, telecommunication terminal equipment, and telecommunication system or installation) that is indispensable to ensure normal intended operation of the telecommunication network.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 dangerous event: Lightning flash to or near the telecommunication line to be protected which causes a dangerous surge voltage due to lightning.

3.2.2 dangerous surge voltage due to lightning: A surge voltage whose peak value U_p is greater than the equipment resistibility or the conductor insulation surge voltage withstand level of the telecommunication line.

3.2.3 electronic system: System incorporating sensitive electronic components such as communication equipment, computers, control and instrumentation systems, radio systems and power electronic installations.

3.2.4 failure of electrical and electronic systems: Permanent damage of electrical and electronic systems due to surges.

3.2.5 lightning flash near a line: Lightning flash striking close enough to a line to be protected that it may cause dangerous surges.

3.2.6 lightning flash to a structure connected to the line to be protected: Lightning flash striking the structure connected to the line to be protected.

3.2.7 line to be protected: Line connected to a structure for which protection is required against the effects of lightning in accordance with this Recommendation.

3.2.8 loss L_X: 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.

3.2.9 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.

3.2.10 node: Point between sections of a telecommunication line.

NOTE – The list of nodes on a telecommunication installation is shown in the reference configuration (clause 5).

3.2.11 physical damage: Damage to a telecommunication line due to mechanical and thermal effects of lightning.

3.2.12 priority service: A priority service is a service where the loss of the telecommunication service may result in loss of life.

3.2.13 protection measures: Measures to be adopted in the telecommunication installation to be protected to reduce the risk.

3.2.14 risk component R_X: Partial risk depending on the source and the type of damage.

3.2.15 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.

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

3.2.17 source of damage: The source of damage depends on the position of the point of strike relative to the considered line:

– Source of damage S_1: Flashes to the structure (the exchange, the customer's building, or remote site) where the telecommunication or the signalling line enters.

– Source of damage S_2: Flashes near the structure (the exchange, the customer's building, or remote site) where the telecommunication or the signalling line enters.

– Source of damage S_3: Flashes to the telecommunication line entering the structure (the exchange, the customer's building, or remote site).

– Source of damage S_4: Flashes near the telecommunication line entering the structure (the exchange, the customer's building, or remote site).

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

NOTE 1 – Typical electrical sources are lightning and AC/DC power systems.

NOTE 2 – Electrical source coupling can be one or more of the following: electric field (capacitive), magnetic field (inductive), conductive (resistive), electromagnetic field.

3.2.19 surge due to lightning: A surge that is caused by lightning through any type of electromagnetic (conductive, inductive and capacitive) coupling.

NOTE – It is characterized by the following five parameters: peak value; front time, T_1; time to half value, T_2 (or time parameters T_1/T_2); steepness; and specific energy.

3.2.20 surge protective device (SPD): Device that restricts the voltage of a designated port or ports, caused by a surge, when it exceeds a predetermined level.

1) Secondary functions may be incorporated, such as a current-limiting device to restrict a terminal current.

2) Typically, the protective circuit has at least one non-linear voltage-limiting surge protective component.

3) An SPD is a combination of a protection circuit and holder.

3.2.21 telecommunication installation: A combination of equipment, systems, finished products and/or components assembled and/or erected by an assembler/installer at a given place to operate together in order to provide telecommunication services.

3.2.22 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.

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

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

DSLAM	Digital Subscriber Line Access Multiplier
EB	Equipotential Bonding
EBB	Equipotential Bonding Bar
EPR	Earth Potential Rise
GDT	Gas Discharge Tube
LEMP	Lightning Electromagnetic Pulse
LPL	Lightning Protection Level
LPS	Lightning Protection System
MDF	Main Distribution Frame
MET	Main Earthing Terminal
MSPD	Multiservice Surge Protective Device
NT	Network Termination
PE	Protective Earthing
RCCB	Residual Current Circuit Breaker
RCD	Residual Current Device
SELV	Safety Extra Low Voltage
SPD	Surge Protective Device
CDMA WLL	Code Division Multiple Access Wireless Local Loop

5 Reference configuration

The telecommunication network to be considered is the physical connection between:

– the switch telecommunication building and the customer's building; or

– two switch telecommunication buildings; or

– two customer's buildings.

The telecommunication network to be protected using this Recommendation is limited to telecommunication lines (buried or aerial cables, shielded or unshielded cables).

Figure 1 shows the reference configurations for the telecommunication lines using metallic symmetric conductors, where the nodes and the cable sections between them can be seen.

The nodes of Figure 1 have the following description:

Node E: Entrance of the exchange building, e.g., main distribution frame (MDF).

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

Node C: Transition between buried and aerial cables.

Node R:	Entrance of remote electronic sites with active equipment, e.g., DSLAM.

Node D:	Transition between shielded and unshielded aerial cables.

Node S:	Entrance of the customer's building.

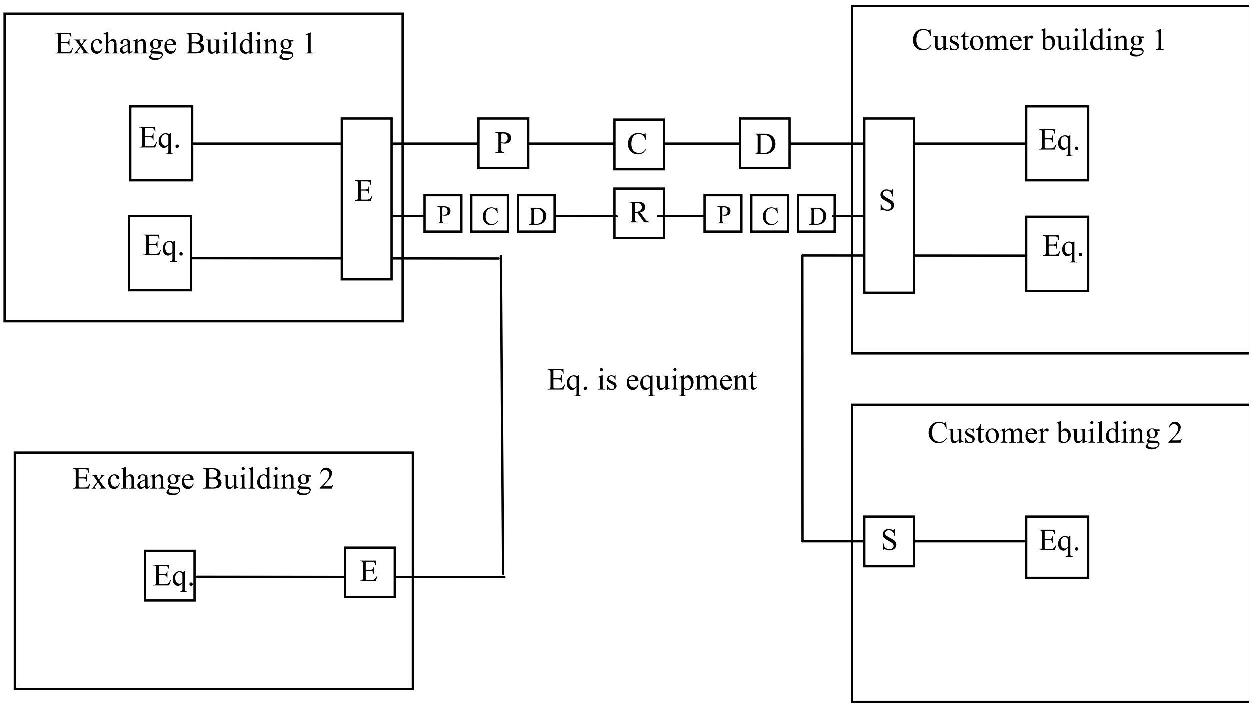


Figure 1 – Reference configuration

6 Explanation of terms

6.1 Damage and loss

6.1.1 Source of damage

The lightning current is the primary source of damage.

In general, the following sources are distinguished by the strike attachment point (Figure 2):

S_1:	Flashes to a structure.

S_2:	Flashes near a structure.

S_3:	Flashes to a service (which includes a telecommunication line).

S_4:	Flashes near a service (which includes a telecommunication line).

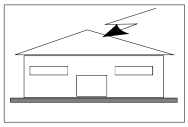
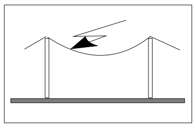
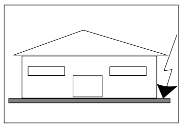
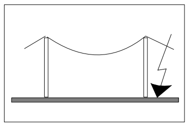
Source of damage	Striking point
S1	
S3	
S2	
S4	

Figure 2 – Lightning as source of damage

6.1.2 Types of damage to persons

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

- type of structure construction, e.g., timber, brick or reinforced concrete;
- type of telecommunication cable, e.g., shielded or unshielded;
- whether or not protection measures have been used at the structure or on the network cable.

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

D1: Injury to living beings by electric shock.

D2: Physical damage (may cause a fire or gas explosion).

D3: Failure of electrical and electronic systems (only where a person has a medical dependency on the telecommunication service).

Lightning striking the telecommunication network can cause:

- a step and touch potential between the equipment, connected to the telecommunication service, and the structure earth environment;
- a flashover within the structure causing a fire or a gas explosion;
- an outage of the telecommunication service due to damage to the physical line itself (both in the network or the structure) and to the telecommunication equipment (both in the network and in the structure).

6.1.3 Types of loss

Each type of damage, alone or in combination with others, may produce a different consequential loss in the object to be protected. The type of loss that may appear depends on the characteristics of the object to be protected.

In general, the following types of loss shall be taken into account:

L_1: Loss of human life

L_2: Loss of service to the public

L_3: Loss of cultural heritage

L_4: Loss of economic value (structure and its contents, service and loss of activity)

The type of loss considered in this Recommendation is:

L_1: Loss of human life

This Recommendation will also consider the risk of injury.

6.2 Risk and risk components

6.2.1 Risk

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

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

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

The risk components, as defined in [IEC 62305-2], which can cause all types of loss, are listed in clauses 6.2.2 to 6.2.5.

6.2.2 Risk components for a structure due to flashes to the structure

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

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

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

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

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

6.2.3 Risk component for a structure due to flashes near the structure

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

6.2.4 Risk components for a structure due to flashes to a line connected to the structure

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

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

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

NOTE 1 – The lines taken into account in this assessment are only the lines entering the structure.

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

6.2.5 Risk component for a structure due to flashes near a line connected to the structure

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

NOTE 1 – The lines taken into account in this assessment are only the lines entering the structure.

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

6.3 Composition of risk components related to a structure

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

R_1: Risk of loss of human life:

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

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

The above formula determines the general risk R_1 for a person inside or outside the structure. The purpose of this Recommendation is to determine the risks of injury associated with the telecommunication service provided over metallic conductors.

It should be understood that the metallic telecommunication service brings a remote earth into the structure. As well as the surges entering the structure from the telecommunication line a lightning strike to the structure or to the power service can cause a touch potential between the telecommunication remote earth and the structure earth.

7 Risk management

7.1 Basic procedure

The following procedure shall be applied:

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

– identification of the risk components to be used, e.g.,
  - electric shock
  - fire and explosion
  - loss of service (priority services only);

– identification of sources of damage
  - direct strikes to telecommunication service (S_3)
  - direct strikes to structure (S_1)
  - direct strikes to non telecommunication services (S_3)
  - indirect strikes to telecommunication service (S_4);

– evaluation of risk R_1;

– evaluation of need of protection, by the comparison of the risk R_1 with the tolerable risk, R_T.

7.2 Tolerable risk R_T

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

A representative value of tolerable risk, R_T, against loss related to loss of human life or injuries due to lightning is given in Table 1.

Table 1 – Typical values of tolerable risk R_T

Types of loss	$R_T(y^{-1})$
Loss of human life or permanent injuries	10^{-5}

7.3 Specific procedure to evaluate the need for protection

7.3.1 Specific procedure to evaluate the need for protection by the telecommunication network operator

For the risk due to lightning strikes to the telecommunication service, the following steps shall be taken:

– identification of the relevant service and its characteristics;

– calculation of the product $N_{Ltelecom} \times P_{LD}$;

– calculation of need of protection, by the comparison of the product with the product limit (a product limit = 0.1 is recommended).

The limit value of the telecommunication cable becomes $L_L = \frac{2500}{N_G \times C_E \times C_I \times P_{LD}}$ where L_L is in metres.

Figure 3 shows the flow chart to evaluate the protection need and for selecting the protection measures.

7.3.2 Specific procedure to evaluate the need for protection by the structure owner

For risk R_1 the following steps shall be taken:

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

– identification of the tolerable risk R_T;

– identification of the risk components to be used, e.g.,

  • electric shock

  • fire and explosion

  • loss of service (priority services only);

– identification of sources of damage

  • direct strikes to structure (S_1)

  • direct strikes to telecommunication service (S_3)

  • direct strikes to non telecommunication services (S_3)

  • indirect strikes to telecommunication and power service (S_4) (priority services only);

– calculation of risk R_1 using the relevant risk components, see Annexes A-C;

– calculation of need of protection, by the comparison of the risk R_1 with the tolerable risk, R_T.

Figure 4 shows the flow chart to evaluate the protection needs and for selecting the protection measures of telecommunication lines.

7.4 Protection measures

Protection measures are directed to reduce the risk according to the type of damage.

Protection measures shall be considered effective only if they conform to the requirements of [ITU-T K.66], [IEC 62305-3] for structure/primary protection and [IEC 62305-4] for equipment protection.

7.5 Selection of protection measures

The selection of the most suitable protection measures shall be made by the protection designer according to the share of each risk component in the total risk and according to the technical and economic aspects of the different protection measures.

Critical parameters shall be identified to determine the more efficient measure to reduce the risk R_1.

For each type of loss, there is a number of protection measures which, individually or in combination, make the condition $R_1 \leq R_T$. The solution to be adopted shall be selected with allowance for technical and economic aspects. A simplified procedure for selection of protective measures is given in Figures 3 and 4. In any case, the installer or planner should identify the most critical risk components and reduce them, also taking into account economic aspects. Figure 3 is used by the telecommunication network operator to determine when to install a GDT at the point of entry of the telecommunication cable/line. Figure 4 is used to perform a full risk assessment.

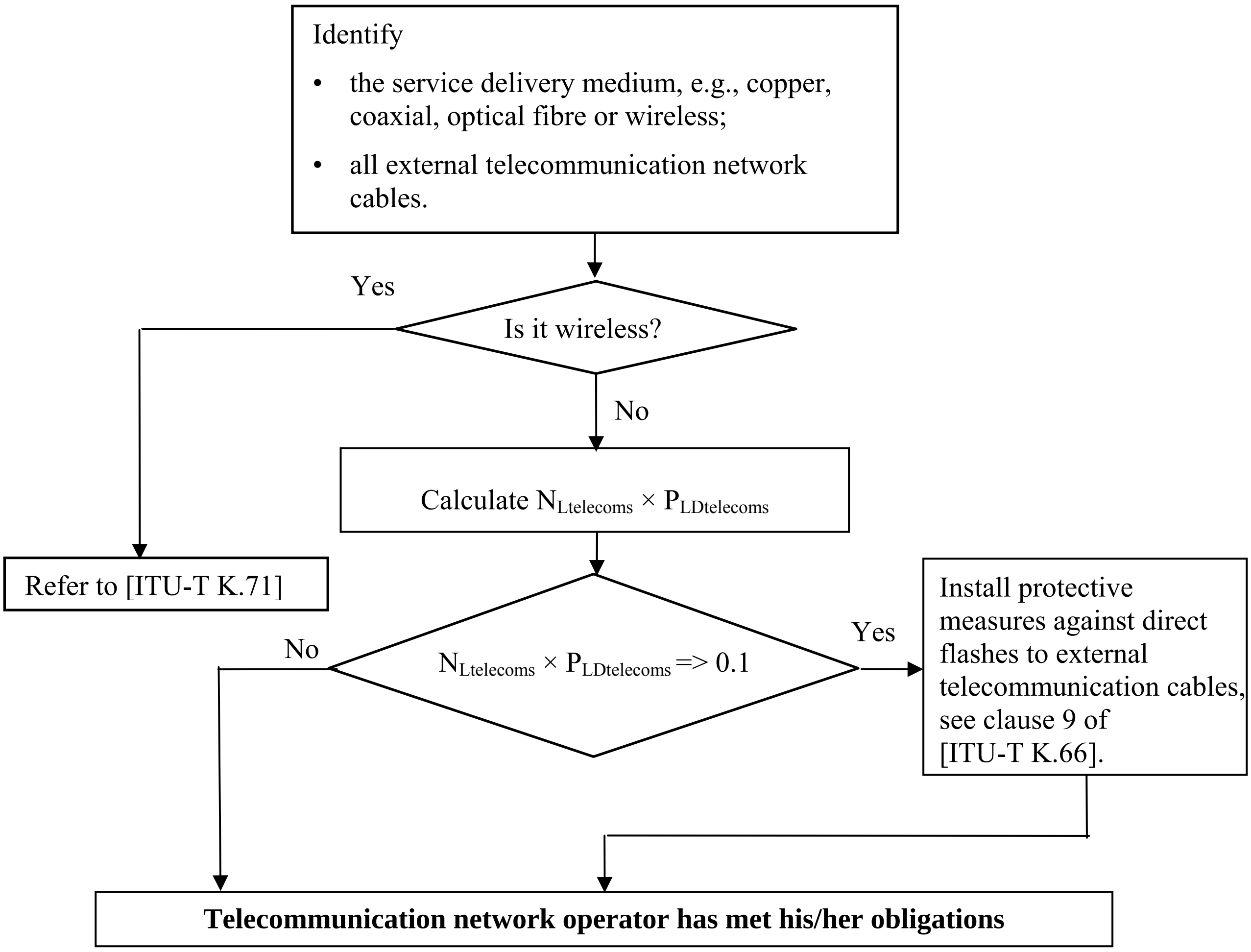


Figure 3 – Procedure for telecommunication operator to determine when to install a GDT at the point of entry of the telecommunication cable/line

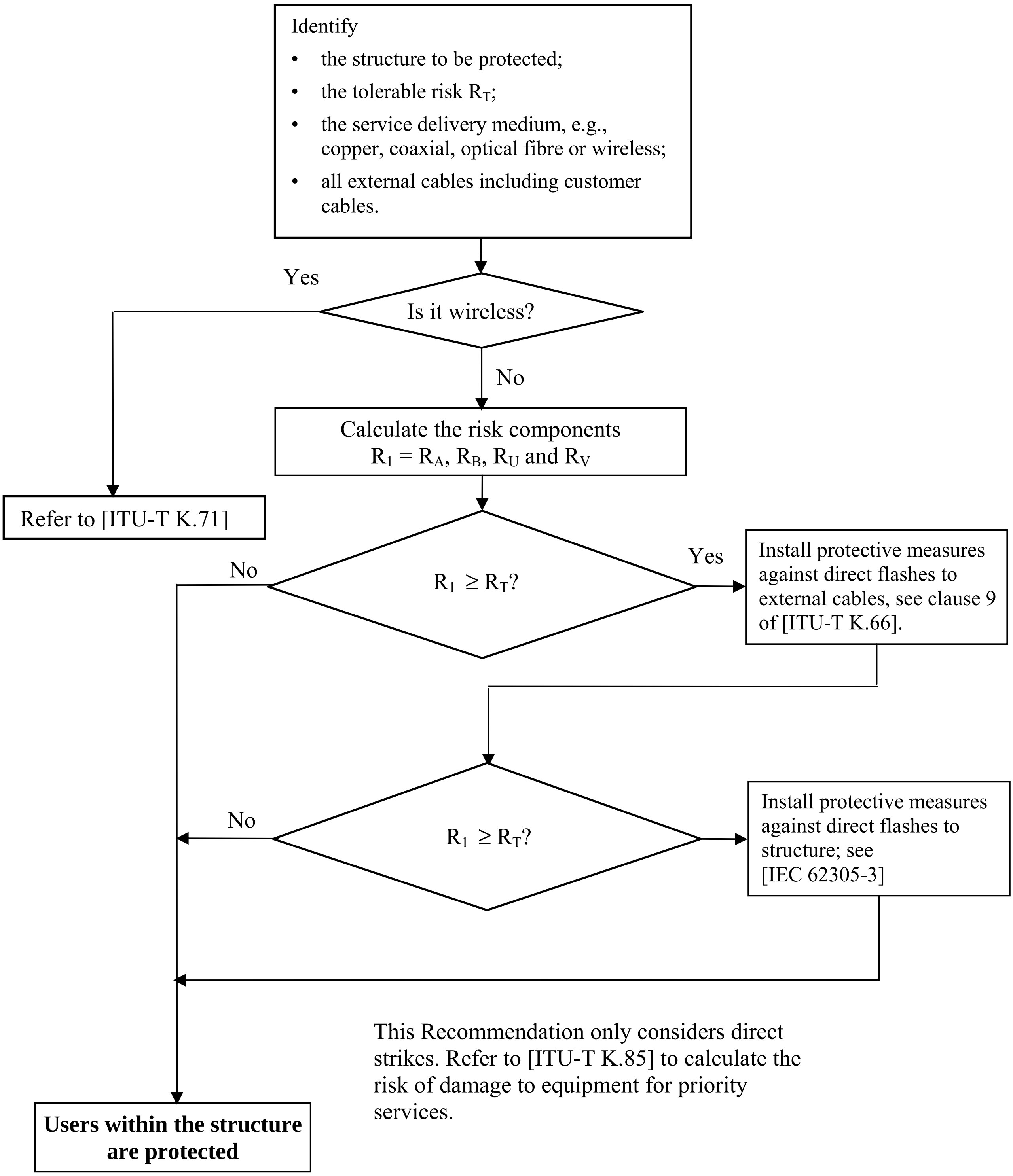


Figure 4 – Procedure for building owner selecting protection measures for the structure

8 Responsibility

It is recommended that responsibility of protection measures be shared, as shown in Table 2.

Table 2 – Responsibility of protection measures

Function	Responsibility
Installation of an LPS	• Building owner
Installation of an effective earthing and bonding system, including the required EBB	• Building owner
Manufacture of equipment with a minimum level of resistibility to the relevant standard (e.g., basic level of [ITU-T K.21] for telecommunication equipment)	• Manufacturer
Use of equipment with the required level of resistibility to the relevant standard	• Network equipment: network operator • Customer equipment: customer/regulator
Structure risk analysis associated with the telecommunication installation	• Network operator/Service owner. It is recommended, as a minimum, that the network operator/service owner calculate the product of the number of direct flashes to the telecommunication line and P_{LD}.
Total structure risk analysis	• Building owner
Installation of SPDs and bonding of metallic pipes and cable screens	• Installation of services SPDs to protect the network (including network equipment within the structure), bonding of cable screens and metallic pipes in the public network: network operator/service owners. • Installation of telecommunication service SPDs to reduce the risk of injury to persons using the telecommunication service: telecommunication network operator/service owner when $N_{Ltelecoms} \times P_{LDtelecoms}$ is ≥ 0.1. The limit value L_L (in metres) of the telecommunication cable becomes $$L_L = \frac{2500}{N_G \times C_E \times C_I \times P_{LD}}$$ • Installation of customer SPDs to prevent injury of occupants within the structure and to protect the structure and its contents, bonding of cable screens and metallic pipes in the private network: building owner.
Customer owned equipment risk analysis and installation of equipment protection, e.g., MSPD	• Equipment owner

Annex A

Assessment of annual number *N* of dangerous events

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

Annex A of [IEC 62305-2] provides the formulas required to calculate the average numbers of strikes influencing structures, aerial lines and underground cables per annum.

A.1 Assessment of the average annual number of dangerous events N_L due to flashes to a line

Edition 2 of [IEC 62305-2] calculates N_L using factor C_E while [b-IEC 62305-2 Ed.1] used factor C_D. Factor C_D includes a factor of 2 for objects on a hilltop or knoll. Factor C_E does not have this factor of 2, as it is a factor originally related the shielding of electromagnetic waves by buildings. Telecommunication network operator experience has shown that cables installed on a hill or along a ridge have a much higher exposure to direct strikes than cables installed on flat ground. To take this higher exposure into account, when considering direct strikes to an aerial or underground cable installed on a hill or along a ridge, a factor of 2 is recommended. It is recommended that the amended factor for C_E given in Table A.1 be used.

Table A.1 – Modified [IEC 62305-2] Table A.4 – Line environmental factor C_E

Environment	C_E
Lines installed on a hill in a rural area[a)]	2
Rural	1
Suburban	0.5
Urban	0.1
Urban with tall buildings[b)]	0.01

a) Experience shows that telecommunication lines installed on a hill in a rural area are more likely to be subjected to a direct strike than lines installed on flat ground. Lines installed along a ridge in a rural area are a particular problem.
b) Buildings higher than 20 m.

The value of the line length L_L used is critical to obtaining a reasonable answer. The actual length of the line can vary from literally tens of m to tens of km. The start of the cable is the closest earthed equipment and the end of the cable is the structure.

Annex B

Assessment of probability P_x of damage for a structure

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

Annex B of [IEC 62305-2] provides the formulas required to calculate the probability that a lightning strike will cause a loss, e.g., injury. This Recommendation only considers direct strikes. Refer to [ITU-T K.85] to calculate the risk of damage to equipment for priority services. A priority service is a service where the loss of the telecommunication service may result in loss of life.

B.1 Probability P_A

Probability P_A according to [IEC 62305-2] can be used to determine the risk of injury taking into account the installation of SPDs.

P_A is equal to $P_{TA} \times P_B$

B.2 Probability P_B

IEC uses P_B to calculate the probability of injury related to physical damage caused by dangerous sparking inside the structure triggering a fire or explosion. This value of P_B is given in Table B.2 of [IEC 62305-2].

B.3 Probability P_C

According to [IEC 62305-2] probability P_C is only used if the life of the building occupant is dependent upon the telecommunication service. This is not considered in this version of ITU-T K.89. Refer to [ITU-T K.85] to calculate the risk of damage to equipment for priority services.

P_C is equal to $P_{SPD} \times C_{LD}$

B.4 Probability P_M

According to [IEC 62305-2] probability P_M is only used if the life of the building occupant is dependent upon the telecommunication service. This is not considered in this version of ITU-T K.89. Refer to [ITU-T K.85] to calculate the risk of damage to equipment for priority services.

P_M is equal to $P_{SPD} \times P_{MS}$

B.5 Probability P_U

The values of probability P_U of injury to living beings inside the structure due to touch voltage by a flash to a line entering the structure depends on the characteristics of the line shield, the impulse withstand voltage of internal systems connected to the line, the protection measures like physical restrictions or warning notices and the isolating interfaces or SPD(s) provided for equipotential bonding at the entrance of the line according to [IEC 62305-3] or [ITU-T K.66].

NOTE 1 – A coordinated SPD system according to [IEC 62305-4] is not necessary to reduce P_U; in this case SPD(s) according to [IEC 62305-3] are sufficient, i.e., it is only necessary to install primary protection on the incoming services.

P_U is equal to $P_{TU} \times P_{EB} \times P_{LD} \times C_{LD}$

where:

P_{TU} depends on protection measures against touch voltages, such as physical restrictions or warning notices. Values of P_{TU} are given in Table B.6 of [IEC 62305-2].

P_{EB} depends on lightning equipotential bonding (EB) conforming to [IEC 62305-3] and on the lightning protection level (LPL) for which its SPDs are designed. Values of P_{EB} are given in Table B.7 of [IEC 62305-2].

P_{LD} is the probability of failure of internal systems due to a flash to the connected line depending on the line characteristics. Values of P_{LD} are given in Table B.8 of [IEC 62305-2]. In this case, U_W is used to determine the probability of a flashover between the telecommunication line and the power line, with the user of the equipment.

C_{LD} is a factor depending on shielding, earthing and isolation conditions of the line. Values of C_{LD} are given in Table B.4 of [IEC 62305-2].

NOTE 2 – When SPD(s) according to [IEC 62305-3] are provided for equipotential bonding at the entrance of the line, earthing and bonding according to [IEC 62305-4] may improve protection.

B.6 Probability P_V

The values of probability P_V of physical damage by a flash to a line entering the structure depend on the characteristics of the line shield, the impulse withstand voltage of internal systems connected to the line and the isolating interfaces or the SPDs provided for equipotential bonding at the entrance of the line according to [IEC 62305-3].

NOTE – A coordinated SPD system according to [IEC 62305-4] is not necessary to reduce P_V; in this case, SPDs according to [IEC 62305-3] are sufficient.

P_V is equal to $P_{EB} \times P_{LD} \times C_{LD}$

where:

P_{EB} depends on lightning equipotential bonding (EB) conforming to [IEC 62305-3] and on the lightning protection level (LPL) for which its SPDs are designed. Values of P_{EB} are given in Table B.7 of [IEC 62305-2].

P_{LD} is the probability of failure of internal systems due to a flash to the connected line depending on the line characteristics. Values of P_{LD} are given in Table B.8 of [IEC 62305-2]. In this case, U_W is used to determine the probability of a flashover between the telecommunication line and the power line, with the user of the equipment.

C_{LD} is a factor depending on shielding, earthing and isolation conditions of the line. Values of C_{LD} are given in Table B.4 of [IEC 62305-2].

B.7 Probability P_W

According to [IEC 62305-2] probability P_W is only used if the life of the building occupant is dependent upon the telecommunication service. This is not considered in this version of this Recommendation. Refer to [ITU-T K.85] to calculate the risk of damage to equipment for priority services.

P_W is equal to $P_{SPD} \times P_{LD} \times C_{LD}$

B.8 Probability P_Z

According to [IEC 62305-2] probability P_Z is only used if the life of the building occupant is dependent upon the telecommunication service. This is not considered in this version of this Recommendation. Refer to [ITU-T K.85] to calculate the risk of damage to equipment for priority services.

P_Z is equal to $P_{SPD} \times P_{LI} \times C_{LI}$

Annex C

Assessment of amount of loss L_X in a structure

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

Edition 2 of [IEC 62305-2] has the following loss calculations for loss of life due to damage D1, see clause 6.1.2.

$L_A = r_t \times L_T \times n_z/n_t \times t_z/8760$

$L_B = r_p \times r_f \times h_z \times L_F \times n_z/n_t \times t_z/8760$

$L_U = r_t \times L_T \times n_z/n_t \times t_z/8760$

$L_V = r_p \times r_f \times h_z \times L_F \times n_z/n_t \times t_z/8760$

Appendix I

Example of a risk assessment according to [IEC 62305-2]

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

I.1 General

The structure to be considered is a customer building in a rural area with a power line and a telecommunication line. The tables below follow the risk assessment example in [IEC 62305-2] and may not include all mechanisms of damage.

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

I.2 Building characteristics

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

Table I.1 – Building characteristics

Parameter	Comment	Symbol	Value	Reference (Note)
Dimensions (m)		$(L_b \cdot W_b \cdot H_b)$	20.0 × 15.0 × 6.0	
Location factor	Isolated	C_{db}	1.0	Table A.1
Probability P_A		P_A	1.0	Equation B.1
Additional protection measures	None	P_{TA}	1.0	Table B.1
Characteristics of structure	None	P_B	1.0	Equation B.2
Shield at the structure boundary	None	K_{S1}	1.0	Equation B.5
Shield internal to the structure	None	K_{S2}	1.0	Equation B.6
Ground flash density	1/km^2/year	N_g	4.0	
NOTE – Table and equation references are to [IEC 62305-2], unless otherwise stated.				

I.3 Characteristics of the services

There are two metallic services entering the building:

– an aerial unshielded low voltage power line;

– an underground unshielded telecommunication line.

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

Table I.2 – Characteristics of the power line

Parameter	Comment	Symbol	Value	Reference (Note)
Soil resistivity (Wm)		ρ	400	
Length (m)	See Note 2	L_L	200	
Height (m)		H_c	6	
Line installation factor	Aerial	C_I	1.0	Table A.2
Line type factor	See Note 2	C_T	–	Table A.3
Line environmental factor	Rural	C_E	1.0	Table A.4
Shield resistance per unit length (Ω/km)	Unshielded			
Probability P_C	None	P_C	1.0	Equation B.3
Probability P_{SPD}	None	P_{SPD}	1.0	Table B.3
Number of conductors entering the structure		m	2	
Collection area for lightning to the line (m^2)		A_L	8 000	Equation A.9
Number of direct lightning strikes to the line		N_L	0.032	Equation A.8
Dimensions of the adjacent structure (m)	None	$(L_a{\cdot}W_a{\cdot}H_a)$		
Number of direct lightning strikes to the adjacent structure		N_{Da}	0.0	
NOTE 1 – Table references are to [IEC 62305-2] unless otherwise specified. NOTE 2 – The power line consists of 100 m between a single phase transformer and the structure. There is 500 m of HV line to another single phase transformer. Therefore $L_L = 100 + 0.2 \times 500 = 200$ m.				

The characteristics of the telecommunication line entering the structure are reported in Table I.3 together with the calculated values of the collection areas (A_l and A_i) and the expected dangerous events (N_L and N_i).

Table I.3 – Characteristics of the telecommunication line

Parameter	Comment	Symbol	Value	Reference (Note)
Soil resistivity (Wm)		ρ	400	
Length (m)		L_L	5 000	
Conductor diameter		mm	0.64	
Line installation factor	Underground	C_I	0.5	Table A.2
Line type factor	No	C_T	1.0	Table A.3
Line environmental factor	Rural	C_E	1	Table A.4
Shield resistance per unit length (Ω/km)	Unshielded			
Probability P_C	None	P_C	1.0	Equation B.3
Probability P_{SPD}	None	P_{SPD}	1.0	Table B.3
Number of conductors entering the structure		m	4	
Collection area for lightning to the line (m^2)		A_L	80 000	Equation A.9
Number of direct lightning strikes to the line		N_L	0.4	Equation A.8

Table I.3 – Characteristics of the telecommunication line

Parameter	Comment	Symbol	Value	Reference (Note)
Dimensions of the adjacent structure (m)	None	$(L_a \cdot W_a \cdot H_a)$		
Number of direct lightning strikes to the adjacent structure		N_{Da}	0.0	
NOTE – Table references are to [IEC 62305-2] unless otherwise stated.				

I.4 Characteristics of the internal systems

The main characteristics of the internal systems connected to the power line and telecommunication line are reported in Table I.4.

Table I.4 – Main characteristics of the internal installations

Parameter	Comment	Symbol	Value	Reference (Note)
Power service port				
Shield resistance per unit length (Ω/km)	Unshielded			Table B.8
Withstand voltage of the equipment	2.5 kV	K_{S4}	0.4	Equation B.7
Installed coordinated SPD protection	Not installed	P_{SPD}	1	Table B.3
Probability factor due to direct lightning to the structure		C_{LD}	1.0	Table B.4
Probability factor due to direct lightning near structure		C_{LI}	1.0	Table B.4
Probability factor due to direct lightning to the line		P_{LD}	1.0	Table B.8
Probability factor due to lightning near the line		P_{LI}	0.3	Table B.9
Probability factor due to strike to structure		P_C	1.0	Equation B.2
Probability factor due to a strike to the line		P_W	1.0	Equation B.10
Probability factor due to a strike near to the line		P_Z	0.3	Equation B.11
Telecommunication service port				
Shield resistance per unit length (Ω/km)	Unshielded			Table B.8
Withstand voltage of the equipment	1.5 kV	K_{S4}	0.667	Equation B.7
Installed coordinated SPD protection	Not installed	P_{SPD}	1	Table B.3
Factor C_{LD}		C_{LD}	1.0	Table B.4
Probability factor due to direct lightning near structure		C_{LI}	1.0	Table B.4

Table I.4 – Main characteristics of the internal installations

Parameter	Comment	Symbol	Value	Reference (Note)
Probability factor due to direct lightning to the line		P_{LD}	1.0	Table B.8
Probability factor due to lightning near the line		P_{LI}	0.5	Table B.9
Probability factor due to strike to structure		P^{C}	1.0	Equation B.2
Probability factor due to a strike to the line		P_W	1.0	Equation B.10
Probability factor due to a strike near to the line		P_Z	0.5	Equation B.11
NOTE – Table and equation references are to [IEC 62305-2] unless otherwise stated.				

I.5 Zones definition in the structure

The following main zones may be defined:

– Z_1 (outside the building);

– Z_2 (inside the building).

For zone Z_1 it is assumed that no people are outside the building. Therefore the risk of shock of people R_A = 0. Because R_A is the only risk component outside the building, zone Z_1 can be disregarded completely.

Inside the building only one zone Z_2 is defined taking into account that:

– both internal systems (power and telecom) extend throughout the building;

– no spatial shields exist;

– losses are assumed to be constant throughout the building.

The resulting factors valid for zone Z_2 are reported in Table I.5.

Table I.5 – Characteristics of Z_2 (inside the building)

Parameter	Comment	Symbol	Value	Reference (Note 1)
Type of floor	Concrete	r_t	10^{-2} (Note 2)	Table C.3
Protection against shock (flash to structure)	None	P_{TA}	1	Table B.1
Protection against shock (flash to line)	None	P_{TU}	1	Table B.6
Risk of fire	Low	r_f	0.001	Table C.5
Protection against fire	None	r_p	1.0	Table C.4
Special hazard	None	h_z	1.0	Table C.6
Loss due to electric shock (D1)	Due to touch and step potential	L_T	0.01	Table C.2

Table I.5 – Characteristics of Z_2 (inside the building)

Parameter	Comment	Symbol	Value	Reference (Note 1)
Loss due to physical damage (D2)	Others	L_F	0.01 (Note 3)	Table C.2
Loss due to failure of internal system	N/A	L_O	N/A	Table C.2
Factor for person in zone	Number of persons in the zone	n_z	1	Section C.3
	Number of persons in the structure	n_t	1	Section C.3
	Time in hours per year exposed to risk		8760	Section C.3
	Resulting parameters	L_A	1×10^{-4}	Equation C.1
		L_B	1×10^{-5}	Equation C.3
		L_U	1×10^{-4}	Equation C.2
		L_V	1×10^{-5}	Equation C.3
NOTE 1 – Table and equation references are to [IEC 62305-2] unless otherwise stated. NOTE 2 – The country house example in section E.2 of [IEC 62305-2] uses an r_t value of 10^{-5}. NOTE 3 – The country house example in section E.2 of [IEC 62305-2] uses an L_f value of 0.1.				

I.6 Expected dangerous events to the structure

The number of expected dangerous events for the building is reported in Table I.6.

Table I.6 – Expected number of dangerous events

Parameter	Comment	Symbol	Value	Reference (Note)
Collection area for structure (m^2)		A_D	2577	Equation A.2
Number of direct lightning strikes to the structure		N_D	0.0103	Equation A.4
NOTE – Clause references are to [IEC 62305-2] unless otherwise stated.				

I.7 Risk assessment for the unprotected structure

I.7.1 Risk assessment of injury (related to R_1)

The values of the probability factors P are reported in Table I.7.

Table I.7 – Risk R_1: values of the probability factors

Probability	Value
P_A	1.0
P_B	1.0
P_U (power)	1.0
P_V (power)	1.0
P_U (telecommunications)	1.0
P_V (telecommunications)	1.0

The risk of injury can be calculated as follows:

$$\textit{Risk of injury} = R_A + R_B + R_U + R_V$$

The values of the risk components related to the building are reported in Table I.8.

Table I.8 – Risk R_1: values of risk components

Risk components	Risk
$R_A = N_D \times P_A \times L_A$	1.03×10^{-6}
$R_B = N_D \times P_B \times L_B$	1.03×10^{-7}
R_U (power) $= N_L \times P_U \times L_U$	3.2×10^{-6}
R_V (power) $= N_L \times P_V \times L_V$	3.2×10^{-7}
R_U (telecommunications) $= N_L \times P_U \times L_U$	4.00×10^{-5}
R_V (telecommunications) $= N_L \times P_V \times L_V$	4.00×10^{-6}
TOTAL	4.87×10^{-5}

The risk R_1 is greater than the tolerable value of 10^{-5}. Therefore, protection measures are necessary.

I.8 Selected protection measures

The main component of the risk is a lightning flash to the two services. Installing SPDs on the two services will significantly reduce the risk.

I.9 Risk assessment related to the protected structure

I.9.1 Assessment of the risk of injury R_1

The values of the relevant probability factors P are reported in Table I.9.

Table I.9 – Risk R_1: values of the probability factors ***(protected structure)***

Probability	Value
P_A	1.0
P_B	1.0
P_U (power)	0.05
P_V (power)	0.05
P_U (telecommunications)	0.01
P_V (telecommunications)	0.01

The values of the risk components related to the protected building are reported in Table I.10.

Table I.10 – Risk R_1: values of the risk components ***(protected structure)***

Risk components	Risk
$R_A = N_D \times P_A \times L_A$	1.03×10^{-6}
$R_B = N_D \times P_B \times L_B$	1.03×10^{-7}
R_U (power) $= N_L \times P_U \times L_U$	1.60×10^{-7}
R_V (power) $= N_L \times P_V \times L_V$	1.60×10^{-8}
R_U (telecommunications) $= N_L \times P_U \times L_U$	4.00×10^{-7}
R_V (telecommunications) $= N_L \times P_V \times L_V$	4.00×10^{-8}
TOTAL	1.75×10^{-6}

The selected protection measures reduce the risk of injury to less than the tolerable risk.

I.10 SPDs

I.10.1 Selection of SPDs

The selection of SPDs has to take into account the expected overcurrent values in the installation point as indicated in [b-ITU-T K.67] for telecommunication cables and [b-IEC 62305-1] for power cables.

[b-ITU-T K.67] states, for a direct strike to a telecommunication cable:

> If the telecommunication or signalling line is unscreened or is not routed in metal conduit, each of the *m* conductors of the line carries an equal part (I_f) of the peak lightning current which may be evaluated by:

$$I_f = \frac{0.25 \times I_p}{n \times m} \text{ kA for an unshielded line}$$

where n = 1 or 2; the latter case applies for example, where telecommunication and power lines are close to each other, e.g., they share the same poles.

The I_f value given by the equation above shall be equal to or lower than the following value:

$$I_f \leq 8 \times A \quad \text{kA}$$

where A is the cross-sectional area of the telecommunication or signalling conductor [mm^2].

Therefore, for I_p = 200 kA, n = 1 (number of cables) and m= 4 (number of conductors),

I_f = 12.5 kA. However, the telecommunication cable conductor diameter is 0.64 mm and therefore I_f is a maximum of 2.57 kA10/350 independent of the LPL Class.

[b-ITU-T K.12] Table 5 requires a Class 3 GDT to withstand a 2.5 kA 10/350 surge current. Therefore, a Class 3 GDT would be suitable for use as point of entry protection on the telecommunication cable. According to [b-IEC 62305-1] Table E.3 this is an LPL Class I protection, i.e., P_{EB} = 0.01.

[b-IEC 62305-1] Table E.2 lists the expected current level on the mains conductors for LPL Class III – IV as 5 kA 10/350. Therefore installing a 5 kA 10/350 rated SPD at point of entry on the mains gives a protection level of LPL Class III – IV with a corresponding P_{EB} of 0.05.

Appendix II

Equipotential bonding

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

II.1 Non-conductive floors

To prevent potential differences due to lightning strikes occurring within a structure, it is generally necessary to bond the service screens, service SPDs and conductive parts of the structure, e.g., metallic window frames and concrete floors, etc. to the MEB. Where the structure has a non-conductive floor it is necessary to consider the necessity of installing a ring earth, see Figure II.1.

Figure 9.2-4 of [ITU-T K.66] shows the use of a buried ring earth to alleviate the problem with long bonding conductors. A use of a buried ring earth also reduces the potential differences between the MEB and the location of the telecommunication equipment user.

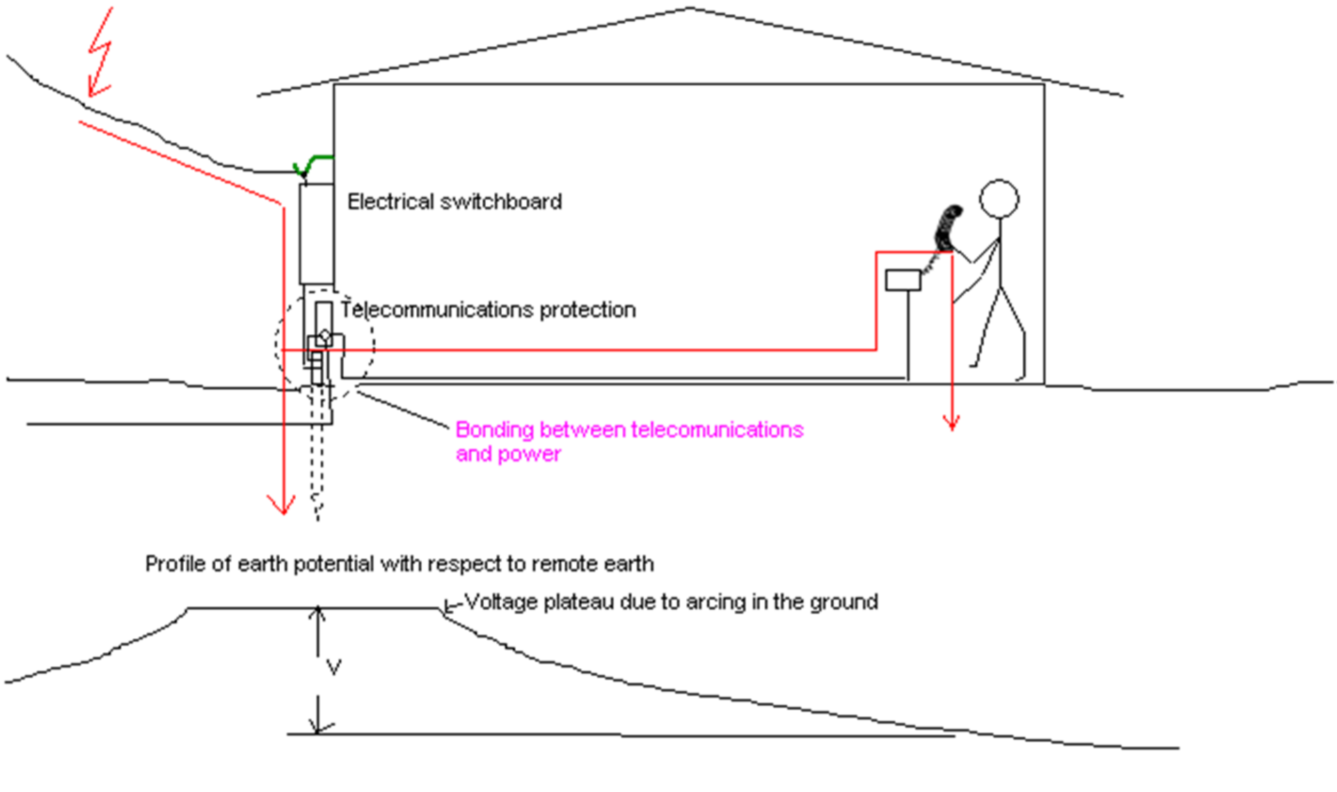


Figure II.1 – Problems associated with non-conductive floors

II.2 Lack of bonding between the telecommunication service, power service and the MEB

The only way to ensure safety in a building is to provide equipotential bonding between the services, the MEB and all touchable metallic parts of the structure. Where it is not possible to directly bond the telecommunication and mains power bonding bars, consideration should be given to using a suitably rated SPD (current and clamping voltage) to provide equipotential bonding under lightning surge conditions but not under power frequency earth potential rise conditions. Where an SPD with a relatively high clamping voltage is used (to prevent conduction during power frequency earth potential rise conditions) it will be necessary to ensure that the equipment has appropriate resistibility and safety requirements.

Appendix III

Cable routing

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

There is a possible issue with potential differences in multi-storied buildings during a lightning strike to the building. [b-IEC 60364-4-44] shows that it may be necessary to route cables in such a way as to minimize coupling into the loop formed by the telecommunication/data and power cables. It may also be necessary to bond the PE conductor and the building CBN at floor level. Bonding in this way will prevent potential differences between the building steel and the PE conductor at floor level and hence the mains and telecommunication/data conductors with respect to the building steel at floor level. Either the equipment protection or breakdown of the equipment insulation will minimize potential differences. Compliance with [b-IEC 62364-4-44] is recommended.

Appendix IV

Risk assessment using Recommendation ITU-T K.47

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

IV.1 Assessment of annual number N of dangerous events

[b-IEC 62305-2 Ed.1] calculates A_L, for an underground cable, using formula containing Rho (resistivity). In [IEC 62305-2] A_L is calculated assuming the resistivity is 400 ohm. Also, the calculation in [b-IEC 62305-2 Ed.1] is simplified compared with [b-ITU-T K.47]. The three formulas, assuming ρ = 400 Ω.m, are listed below.

[b-IEC 62305-2 Ed.1] $A_L = L_L \times 6 \times H$ for aerial cables. When H = 6, A_L = 36.

$A_L = L_L \times \sqrt{\rho} = L_L \times 20$ for underground cables

[IEC 62305-2] $A_L = C_I \times L_L \times 40$ for both aerial and underground cables

where C_I = 1 for aerial cables and 0.5 for underground cables, which is a similar result to [b-IEC 62305-2 Ed.1].

[b-ITU-T K.47] $A_L = 2 \times L_L \times 3 \times H$ for aerial cables. This is similar to both editions of [IEC 62305-2]

$A_L = L_L \times 2 \times \left(2.91 + 0.191 \times \sqrt{\rho}\right) = L_L \times 13.46$ for underground cables when ρ = 400 Ω.m.

It is possible to calculate A_L, for telecommunication and power cables, using [b-ITU-T K.47] as allowed by [IEC 62305-2]. This means that the calculated number of injuries will be less than that calculated using [b-IEC 62305-2 Ed.1] and [IEC 62305-2].

[IEC 62305-2] calculates N_L using factor C_E while [b-IEC 62305-2 Ed.1] used factor C_D. Factor C_D includes a factor of 2 for objects on a hilltop or knoll. Factor C_E does not have this factor of 2 as it is a factor originally related the shielding of electromagnetic waves by buildings. Telecommunication network operator experience has shown that cables installed on a hill or along a ridge have a much higher exposure to direct strikes than cables installed on flat ground. To take this higher exposure into account, when considering direct strikes to an aerial or underground cable installed on a hill or along a ridge, a factor of 2 is recommended.

The frequency of damage for aerial and buried cables (F'_{Va} and F'_{Vb}) can be calculated by:

$$F'_{Va} = 2N_g \times [L - 3(H_a + H_b)] \times D \times p(I_a) \times C_e \times 10^{-6} \quad \text{[damages/year]}$$

$$F'_{Vb} = 2N_g \times [L - 3(H_a + H_b)] \times D \times p(I_a) \times C_e \times 10^{-6} \quad \text{[damages/year]}$$

NOTE – The modified factor C_e is now used for the ITU-T K.47-type calculation. The factor D is calculated as follows.

a) **Buried cable**

The striking distance for buried cables is calculated as a function of earth resistivity, as follows:

$D = 0.482\,(\rho)^{1/2}$ for $\rho \le 100 \Omega.m$

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

$D = 0.283\,(\rho)^{1/2}$ for $\rho \ge 1000 \Omega.m$

b) **Aerial cables**

For aerial cables, the striking distance is given by the following equation:

$$D = 3H[m]$$

where:

H line height [m], which shall be between 4 m and 15 m.

Where the value of the resistivity is not known, it is recommended that a value of 400 ohm.m be used.

IV.2 Assessment of Factor P_{LD} for shielded cables

Table B.8 of [IEC 62305-2] is calculated assuming a soil resistivity of 100 ohm.m. If Table B.8 is used for a structure in a high resistivity area the risk assessment may indicate that protection is not required. Where the soil resistivity is greater than 100 ohm.m, it is more accurate to use the following formulas from [b-ITU-T K.47]:

$$I_s = \frac{10^3 \, U_w}{K \, R \, \rho^{1/2}}$$

where:

- K is the waveshape factor for lightning current, $K = 8\ (\text{m}/\Omega)^{1/2}$;
- R is the sheath resistance per unit length, in Ω/km (for cable with sheath and armouring, R is given by the parallel association between the sheath and the armouring resistance values per unit length);
- U_w is the hazardous voltage (4 kV) as indicated in Table VI.2 of [ITU-T K.89];
- ρ is the soil resistivity, in Ω.m.

Now the failure current $I_a = 2 \times I_s$.

The reduction factor P_{LD} is the probability of I_a occurring and this is determined by

$p\ (I_a)$ is the stroke current probability factor:

$$p(I_a) = 10^{-2} \exp(a - b\, I_a) \qquad \text{for } I_a \geq 0$$

where:

$a = 4.605$	and	$b = 0.0117$	for $I_a \leq 20$ kA
$a = 5.063$	and	$b = 0.0346$	for $I_a > 20$ kA

Appendix V

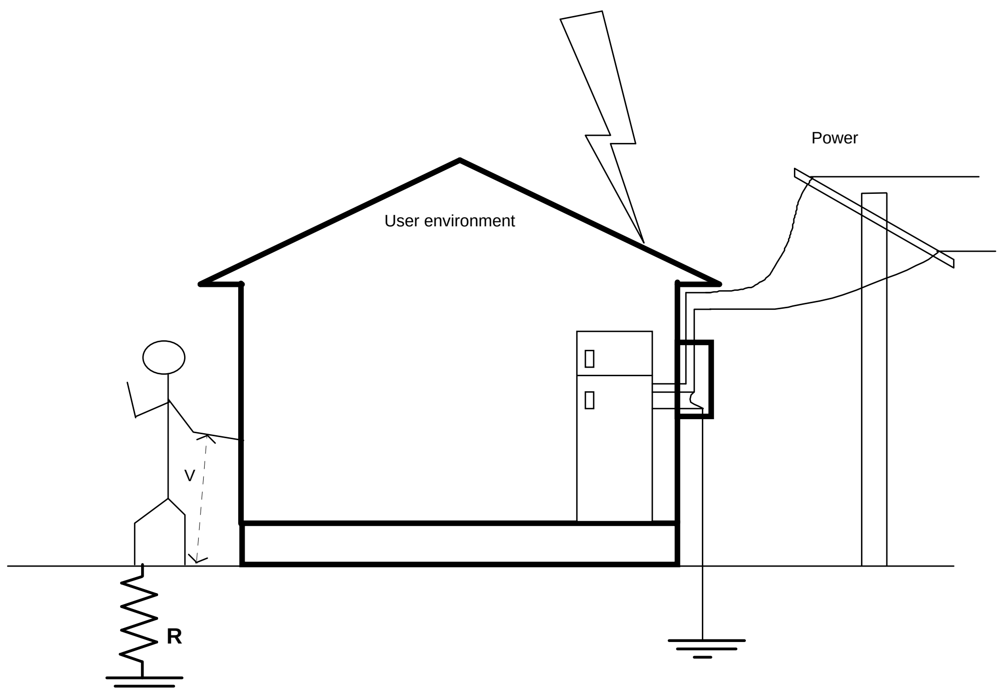
Mechanisms of damage

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

V.1 Electric shock

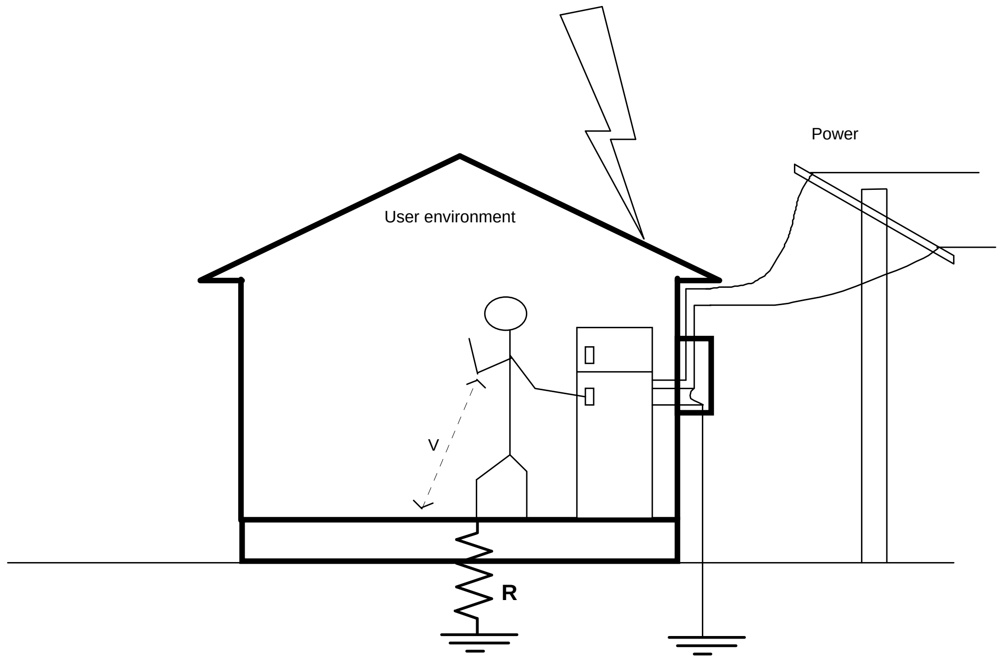
Figure V.1 shows a touch potential outside the structure. Figures V.2-V.9 illustrate the mechanisms by which customers, inside the structure, are exposed to electric shock. These can be summarized as the following.

– Lightning strike to structure:
  - touch potential earthed object to floor;
  - touch potential earthed object to remote telecommunication earth;
  - touch potential floor to remote telecommunication earth.
– Lightning strike to power line:
  - touch potential earthed object to floor;
  - touch potential earthed object to remote telecommunication earth;
  - touch potential floor to remote telecommunication earth.
– Lightning strike to telecommunication line:
  - touch potential telecommunication line to earthed object;
  - touch potential telecommunication line to floor.



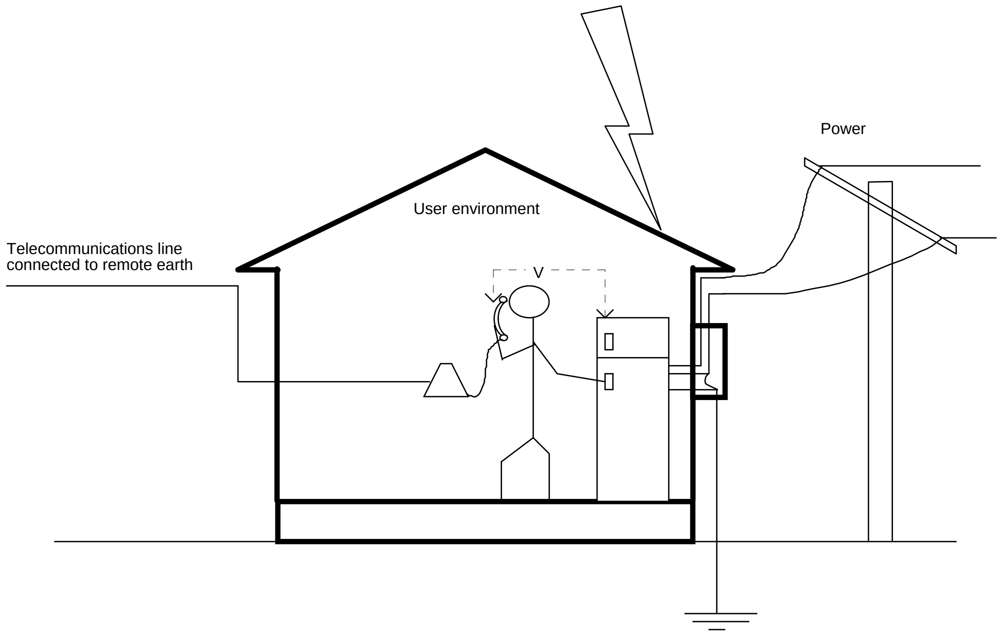
NOTE – This risk is **not** included in this Recommendation.

Figure V.1 – Direct strike to structure (touch potential between the structure and the ground outside the structure)



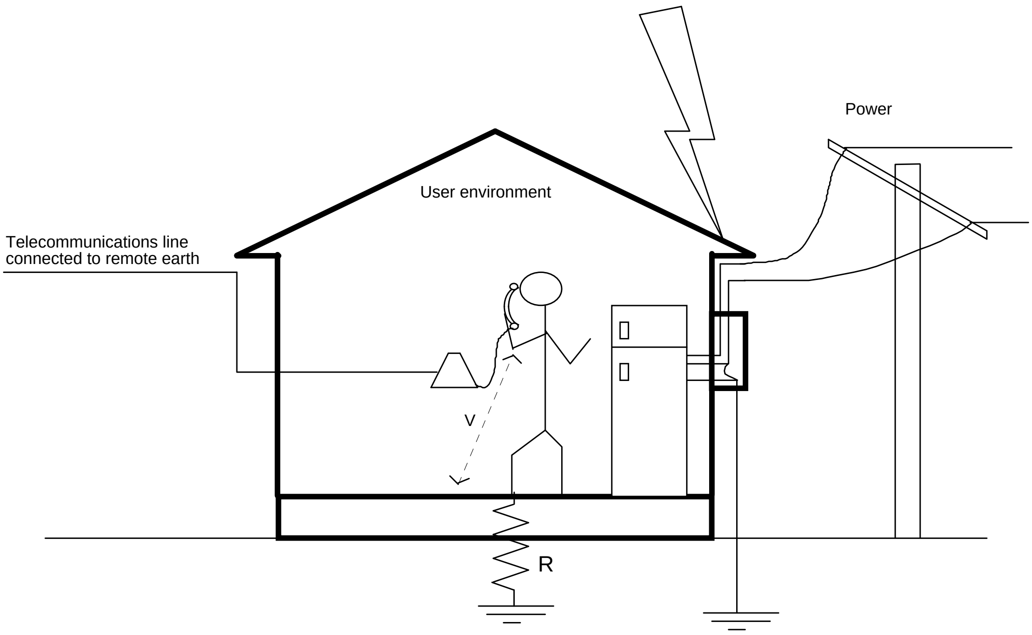
NOTE – This risk is **not** included in this Recommendation.

Figure V.2 – Direct strike to structure (touch potential between an earthed object and the floor of the structure)



NOTE – This risk is **not** included in this Recommendation.

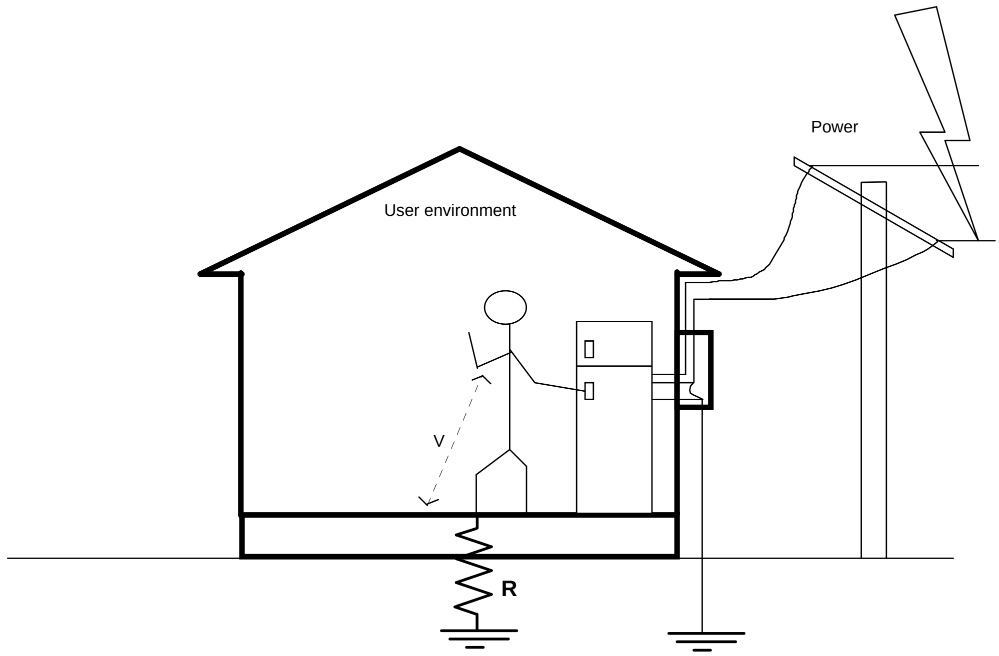
Figure V.3 – Direct strike to structure (touch potential between an earthed object and the telecommunication line which is connected to a remote earth)



NOTE – This risk is included in this Recommendation.

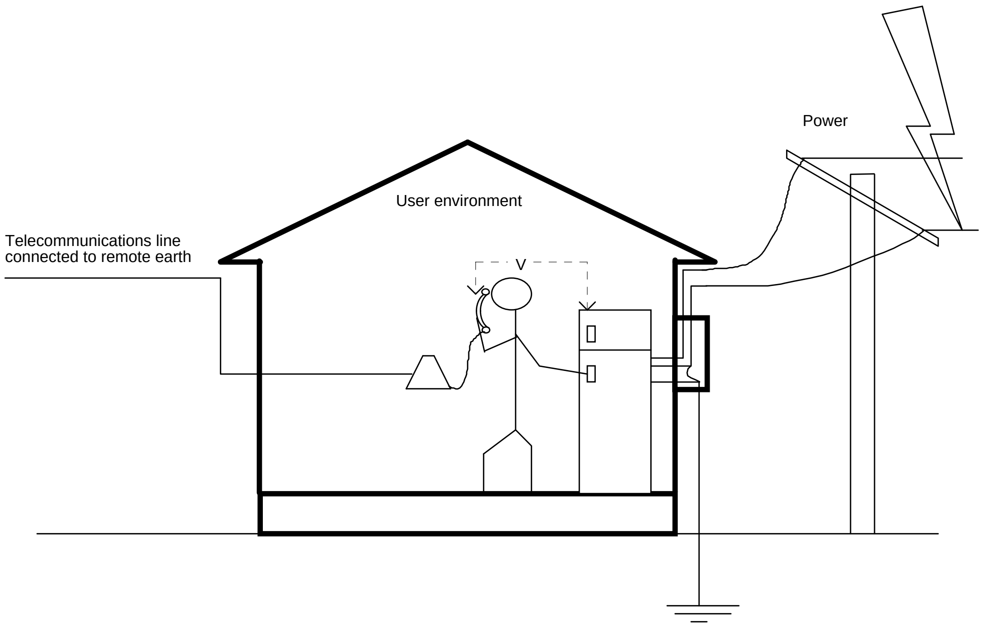
Figure V.4 – Direct strike to structure (touch potential between the structure floor and the telecommunication line which is connected to a remote earth)

It should be noted that although the lightning strikes the structure and goes to earth, the solution to reducing this specific risk is to install point of entry SPDs on the telecommunication line, which will bond the telecommunication line to the MET under surge conditions.



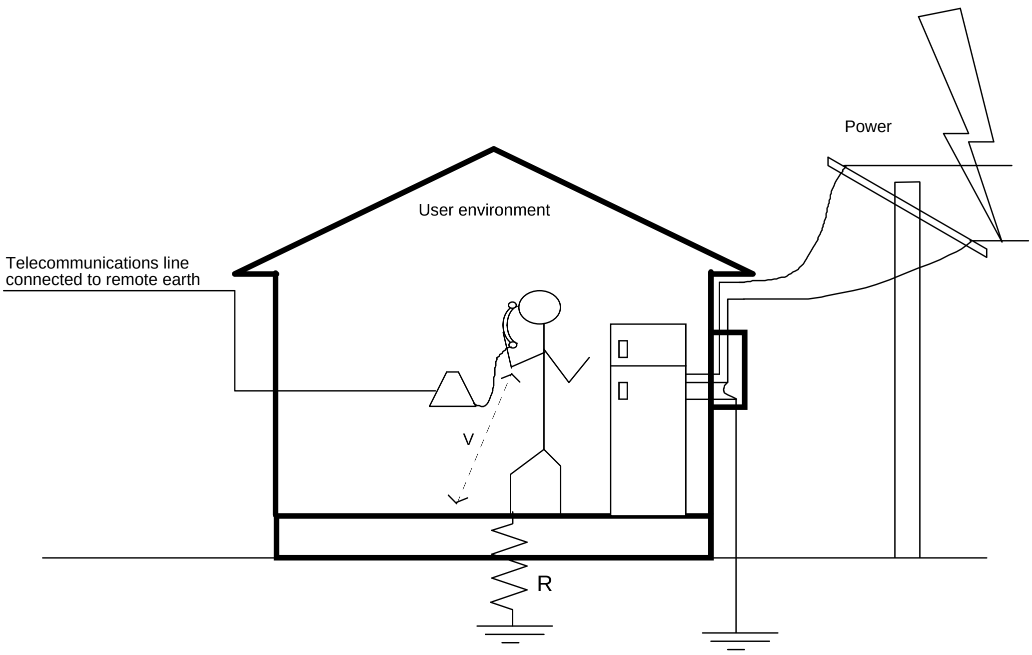
NOTE – This risk is **not** included in this Recommendation.

Figure V.5 – Direct strike to overhead power line (touch potential between an earthed object and the floor of the structure)



NOTE – This risk is currently **not** included in this Recommendation.

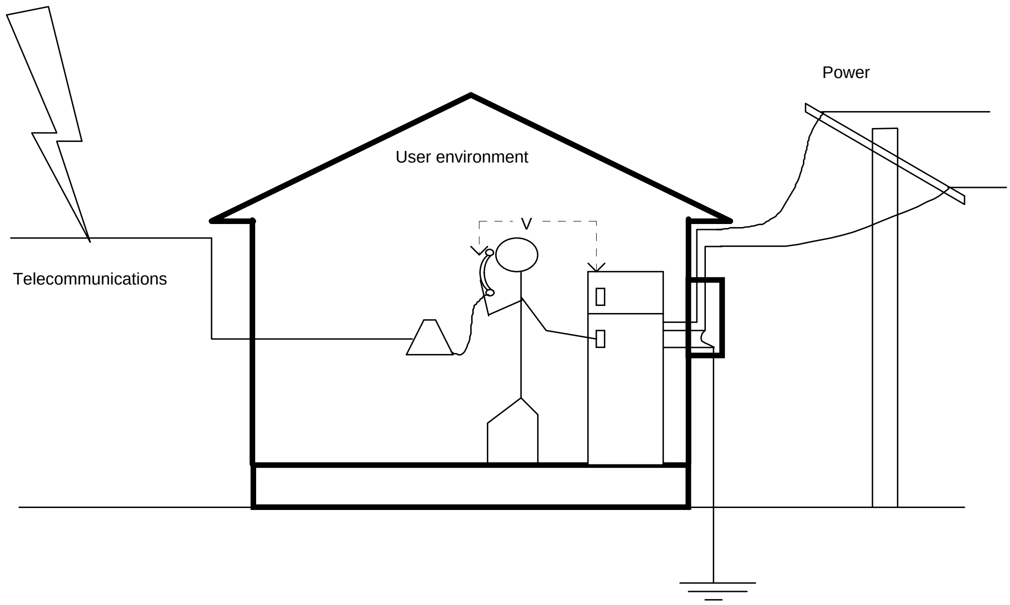
Figure V.6 – Direct strike to a power line (touch potential between an earthed object and the telecommunication line which is connected to a remote earth)



NOTE – This risk is considered in this Recommendation.

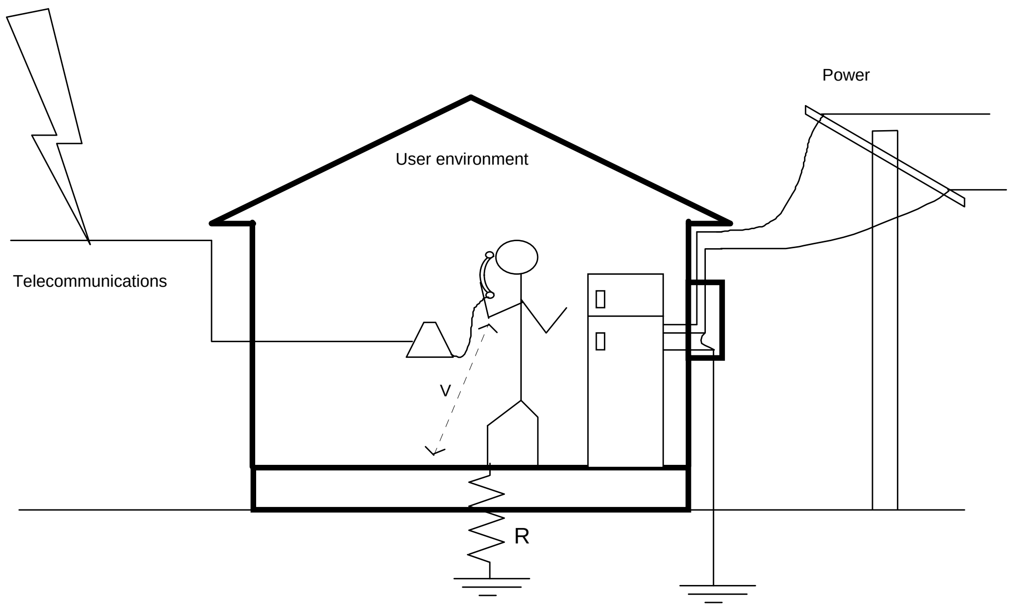
Figure V.7 – Direct strike to a power line (touch potential between the structure floor and the telecommunication line which is connected to a remote earth)

It should be noted that although the lightning strikes the power line and goes to earth, the solution to reducing this specific risk is to install point of entry SPDs on the telecommunication line, which will bond the telecommunication line to the MET under surge conditions.



NOTE – This risk is currently **not** considered in this Recommendation.

Figure V.8 – Direct strike to telecommunication line (touch potential between the telecommunication line and an earthed object)



NOTE – This risk is considered in this Recommendation.

Figure V.9 – Direct strike to telecommunication line (touch potential between the telecommunication line and the structure floor)

V.2 Fire or explosion

A strike to the structure may cause a fire or explosion due an electrical arc occurring. This arc can occur in two ways as follows.

– The flash directly arcs to wiring or metallic parts within the roof or walls of the building (includes strike to LPS).

– The resulting EPR due to current conducted in the structure earth:
  - causes a flashover in the mains-powered telecommunication equipment or telecommunication equipment with an SELV port;
  - causes excessive current in SPDs;
  - causes a flashover to a telephone or to the internal cable.

– A strike to the power line causes an EPR. The resulting EPR:
  - causes a flashover in the mains-powered telecommunication equipment or telecommunication equipment with an SELV port;
  - causes excessive current in SPDs;
  - causes a flashover to a telephone or to the internal cable.

– A strike to the telecommunication line:
  - causes a flashover in the mains-powered telecommunication equipment or telecommunication equipment with an SELV port;
  - causes excessive current in SPDs;
  - causes a flashover to a telephone or to the internal cable.

Appendix VI

Required current or voltage to cause injury

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

The energy developed by the lightning overvoltage across the human body impedance could be hazardous. The information provided in this appendix is based on [b-Day].

The evaluation of the risk of injury to a person touching electrical and electronic equipment inside a structure due to lightning requires the investigation of several scenarios relevant to the hazard of electric shock in the event of lightning overvoltages incident on electrical and/or electronic equipment.

The first scenario is related to overvoltages coming from a hazardous circuit, i.e., the mains, due to flashes to or near a power line. If the insulation between the outer enclosure part in direct contact with the human body and the hazardous circuit breaks down during the lightning surge, the user of the equipment inside the structure is exposed to overvoltages which can cause an injury depending on the energy dissipated through the human body. The user can also be exposed to the hazardous circuit.

The second scenario is related to overvoltages coming from the telecommunication or signal circuit due to flashes to or near the telecommunication or signal line. If the insulation between the outer enclosure part, in direct contact with the human body, and the telecommunication or signal circuit breaks down, the user will be exposed to overvoltages. This could cause an injury depending of the energy dissipated through the human body. A failure of the insulation between the telecommunication or signal circuit and the hazardous circuit, i.e., the mains, can result in hazardous condition as in the first scenario.

A strike to, or near to, the structure can cause the above scenarios.

The risk assessment of injury to persons touching electrical and electronic equipment inside a structure requires the evaluation of the above mentioned hazardous overvoltages causing failure of circuit insulation.

In order to more accurately calculate the risk of injury, the hazardous voltage needs to be determined. This has been determined for two waveshapes using data from [b-IEC 60479-1] and [b-IEC 60479-2]. The waveshape used for direct strikes is 10/350 µs, as indicated by Annex E of [b-IEC 62305-1], and for indirect strikes is 8/20 µs.

The impulse peak current flowing through the human body impedance R_U is given by the following equation:

$$I_{Cp} = \frac{U_U}{R_U}$$

where:

U_U is the voltage drop on the human body resistance;

R_U is the human body resistance assumed equal to 500 Ω;

According to [b-IEC 60479-2], the sinusoidal current magnitude (I_{Brms}) having the same specific fibrillating energy of the impulse current (I_{Cp}) of a capacitor discharge, with the time constant T, is given by the following equation:

$$I_{Cp} = \sqrt{6} \times I_{Brms}$$

The impulse duration (t_i) is assumed equal to 3×T [b-IEC 60479-2]

$$t_i = 3 \times 1.44 \times T_2$$

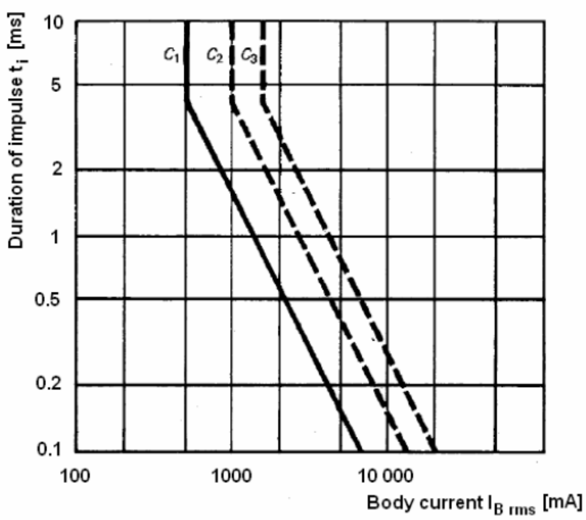
where:

T_2 is the time to half value of the overvoltage waveshape.

This duration gives the current flowing through the human body which can cause a fibrillation risk of 5% in the curve C2 of Figure VI.1, taken from [b-IEC 60479-2].

Neglecting the contact resistance of the user's feet to earth, then U_U is equal to peak value of the overvoltage U_p. Table VI.1 gives the peak value U_p for the various waveshapes. However, the peak value of the overvoltage should be at least equal to the insulation voltage withstand value (e.g., 4 kV for equipment installed in category II of LV system and complying with basic resistibility requirements).

NOTE – The effects of contact resistance are taken into account in the risk component through the evaluation of the loss, according to the IEC approach [IEC 62305-2].



NOTE – Figure 20 of [b-IEC 60479-2].

Figure VI.1 – Threshold of ventricular fibrillation (curve C1: no fibrillation, C2: 5 % of fibrillation, C3: 50 % of fibrillation)

Table VI.1 – Impulse peak voltage U_p and duration (t_i) causing a 5% probability of fibrillation risk

T_2 (µs)	T_i (ms)	I_{Brms} (A)	I_{Cp} (A)	U_p (kV)
700	3.024	1.2	3	1.5
350	1.512	2	5	2.5
20	0.0864	13	32	16

A lightning flash near a power line causes an induced overvoltage at the equipment input inside the building which is assumed to be represented by a time to half value in order of 20 µs, as shown in [b-Day]. In this case, U_U is equal to peak value U_p of the overvoltage, Table VI.1 gives the peak value U_p of about 16 kV.

To consider the likely effects of a lightning surge to the power or telecommunication line it is necessary to look at the various types of equipment. The standard [b-IEC 60950-1] defines classes of equipment as follows.

Class I equipment: Equipment where protection against electric shock is achieved by:

– using basic insulation and
– providing a means of connection to the protective earthing conductor in the building wiring those conductive parts that are otherwise capable of assuming hazardous voltages if the basic insulation fails.

NOTE – Class I equipment may have parts with double insulation or reinforced insulation.

Class II equipment: Equipment in which protection against electric shock does not rely on basic insulation only, but in which additional safety precautions, such as double insulation or reinforced insulation are provided, there being no reliance on protective earthing.

Class III equipment: Equipment in which protection against electric shock relies upon supply from SELV circuits and in which hazardous voltages are not generated.

Based on these three definitions, five types of equipment will be considered as follows.

1 Remote powered telephone

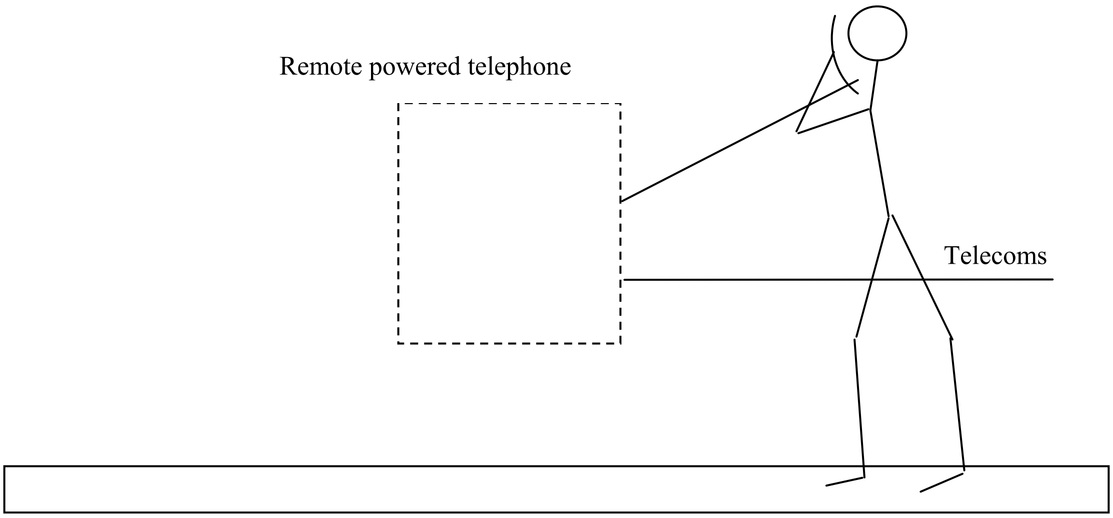


Figure VI.2 – Remote powered telephone

Strike to the telecommunication line: The hazardous voltage is 1.5 kV (10/700 µs). However this is below the breakdown voltage of the handset required by [b-IEC 60950-1]. Section 6.2.2.1 of this standard requires an impulse insulation withstand voltage of 2.5 kV. In this case, the hazardous voltage equals the breakdown voltage. Some national regulators may require a higher breakdown voltage e.g., Australia, which requires 7 kV.

2 Class I equipment

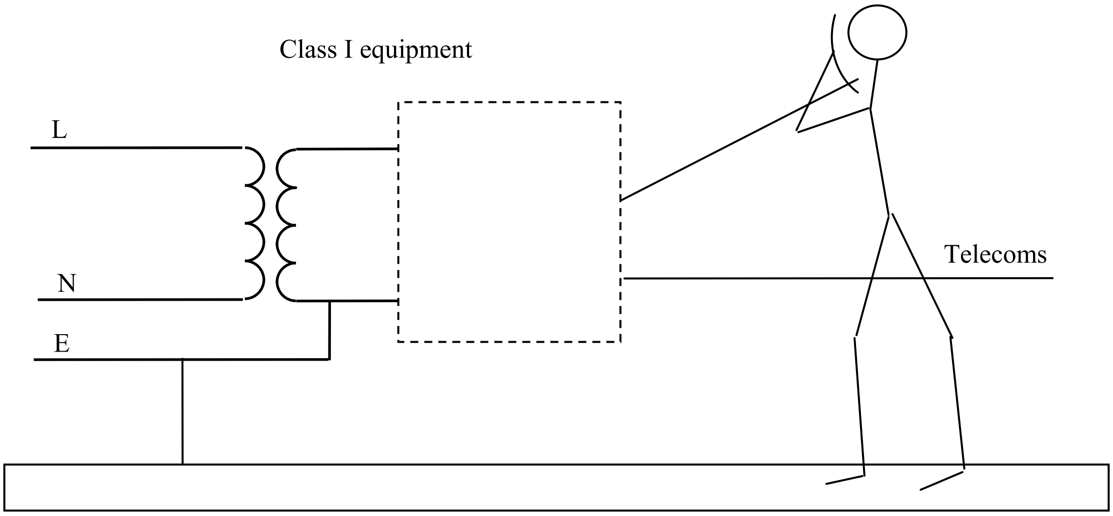


Figure VI.3 – Class I equipment

Strike to power line: A flashover primary to secondary would result in a V = L × di/dt with a short tail (<5 µs). The mains is earthed and the hazardous voltage is 16 kV (8/20 µs).

Strike to the telecommunication line: The hazardous voltage is 1.5 kV (10/700 µs). There are two possible breakdown paths. One is to earth (breakdown requirement is 1.5 kV AC) and the other is to the user (breakdown requirement is 1.5 kV AC). It is assumed for Class I equipment that there will be earthed SPDs on the telecommunication line within the equipment. Operation of these SPDs will ensure a current path to earth resulting in a V = L × di/dt with a short tail (<5 µs). The mains is earthed and the hazardous voltage becomes 16 kV (8/20 µs).

3 Class II equipment

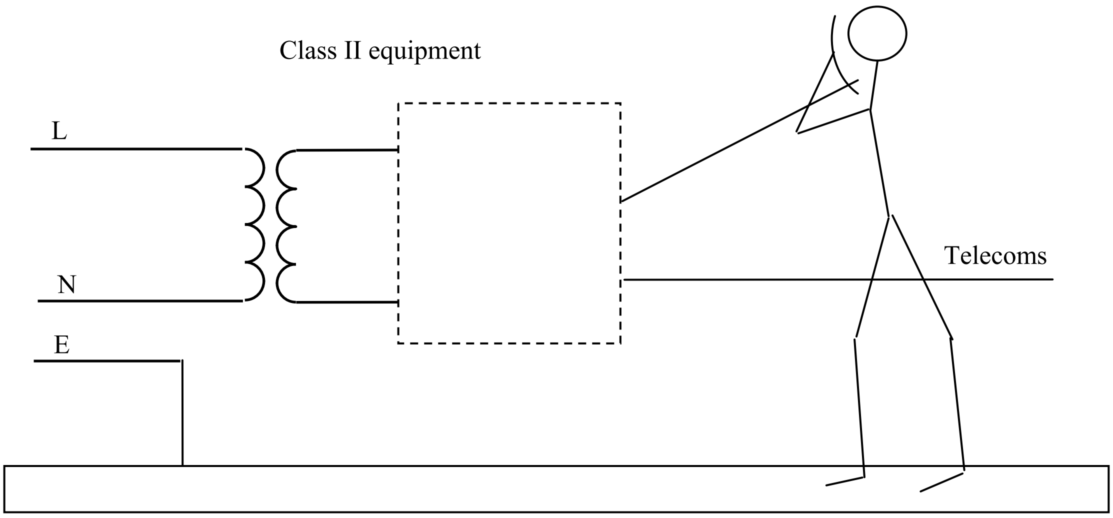


Figure VI.4 – Class II equipment

Strike to power line: A flashover primary to secondary may occur above 4 kV and the user is exposed to mains. The hazardous voltage is 4 kV.

Strike to the telecommunication line: A flashover secondary to primary may occur above 4 kV and the user is exposed to mains. The hazardous voltage is 4 kV.

In those cases where the mains current will be disconnected due to the operation of an EBR, RCCB or RCD, the user is still exposed to a hazardous lightning overvoltage of 4 kV, or greater, with a 10/700 waveshape.

4 Class III equipment with a Class I power supply

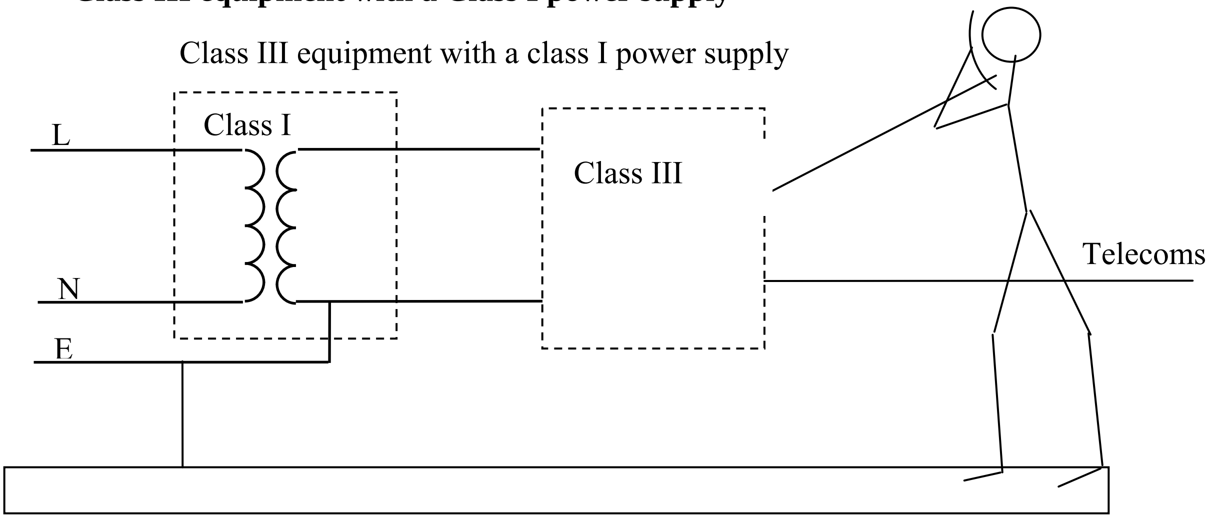


Figure VI.5 – Class III equipment with a Class I power supply

Strike to power line: A flashover primary to secondary would result in a V = L × di/dt with a short tail (<5 µs). The mains is earthed and the hazardous voltage is 16 kV (8/20 µs).

Strike to the telecommunication line: The hazardous voltage is 1.5 kV (10/700 µs). There are two possible breakdown paths. One is to earth (breakdown requirement is 1.5 kV AC) and the other is to the user (breakdown requirement is 1.5 kV AC). It is assumed, for Class III equipment with a Class I power supply, that there will be earthed SPDs on the telecommunication line within the equipment. Operation of these SPDs will ensure a current path to earth resulting in a V = L × di/dt with a short tail (<5 µs). The mains is earthed and the hazardous voltage becomes 16 kV (8/20 µs).

5 Class III equipment with a Class II power supply

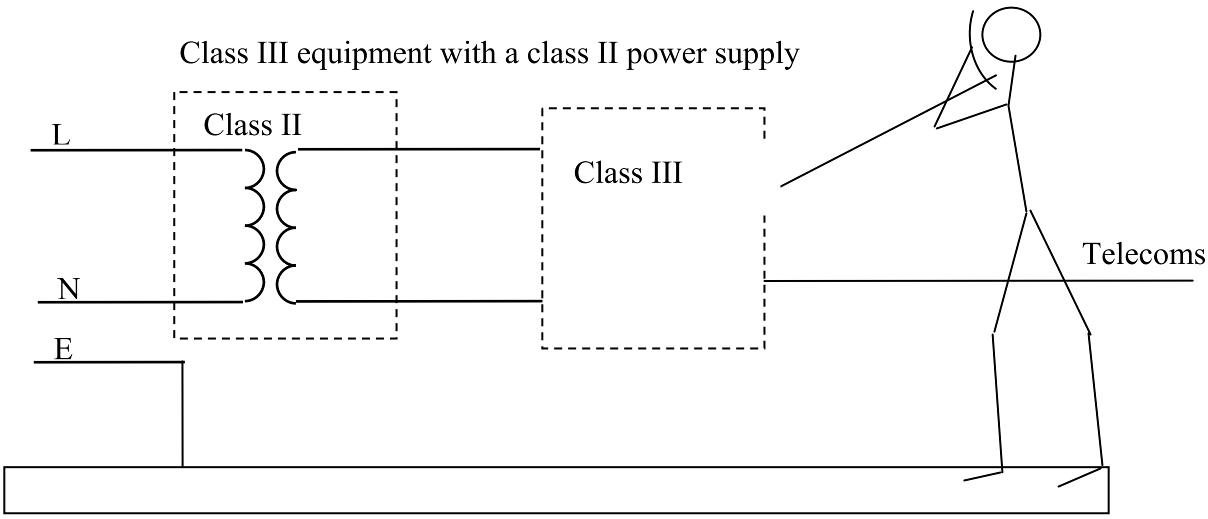


Figure VI.6 – Class III equipment with a Class II power supply

Strike to power line: A flashover primary to secondary may occur above 4 kV and the user is exposed to mains. The hazardous voltage is 4 kV.

Strike to the telecommunication line: A flashover secondary to primary may occur above 4 kV and the user is exposed to mains. The hazardous voltage is 4 kV.

In those cases where the mains current will be disconnected due to the operation of an EBR, RCCB or RCD, the user is still exposed to a hazardous lightning overvoltage of 4 kV, or greater, with a 10/700 waveshape.

Table VI.2 – Resulting hazardous peak voltage U_p

Class of equipment	Hazardous voltage
Remote powered telephone	4 kV lightning (10/700)
I	16 kV lightning. (< 8/20 µs)
II	4 kV (AC mains or lightning (10/700))

In conclusion, the impulse hazardous voltage of a remote powered telephone is a lightning overvoltage of 4 kV, or greater, with a 10/700 waveshape.

– Class I equipment is therefore 16 kV as the tail of the waveshape will then become < 20 µs (inductive voltage along the earth conductor).

– Class II equipment is 4 kV due to exposure to the mains voltage when the lightning surge damages the insulation between the telecommunication line and the mains circuit as well as the insulation to the user. In those cases where the mains current will be disconnected due to the operation of an EBR, RCCB or RCD, the user is still exposed to a lightning overvoltage of 4 kV or greater with a 10/700 waveshape.

The worst-case scenario, considering all of the above methods of powering, is that the hazardous voltage is 4 kV.

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