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Part 3: Physical damage to structures and life hazard

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INTERNATIONAL STANDARD

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62305-3

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Protection against lightning – Part 3: Physical damage to structures and life hazard

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

PROTECTION AGAINST LIGHTNING –

Part 3: Physical damage to structures and life hazard

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC national committees). The object of the IEC is to promote international cooperation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes international standards, technical specifications, technical reports, publicly available specifications (PAS) and guides (hereafter referred to as "IEC publication(s)"). Their preparation is entrusted to technical committees; any IEC national committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International standard IEC 62305-3 has been prepared by IEC technical committee 81: Lightning protection.

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The text of this first edition of IEC 62305-3 is compiled from and replaces

- IEC 61024-1, first edition (1990).
- IEC 61024-1-2, first edition (1998).

The text of this standard is based on the following documents:

FDIS	Report on voting
81/264/FDIS	81/269/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above Table.

This publication has been drafted, as close as possible, in accordance with the ISO/IEC Directives, Part 2.

IEC 62305 consists of the following parts, under the general title *Protection against lightning*:

Part 1: General principles

Part 2: Risk management

Part 3: Physical damage to structures and life hazard

Part 4: Electrical and electronic systems within structures

Part 5: Services¹

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC website "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be:

- reconfirmed;
- withdrawn;
- replaced by a revised edition; or
- amended.

In the United States, based on the requirements of NFPA 780: Standard for the Installation of Lightning Protection Systems 2004 Edition and practical experience in the use of horizontal earth electrodes, the minimum length of horizontal earth electrodes is not required to be twice that required for vertical electrodes.

In France, Portugal and Spain:

- natural components cannot substitute as lightning protection components but may be used to complete/enhance the LPS;
- aluminium solid round diameters should be extended from 8 mm to 10 mm;
- stranded conductors cannot be used as down-conductors;
- diameter of solid round conductors should be extended from 16 mm to 18 mm;
- hot dip galvanized steel solid tape thickness should be extended from 2 mm to 3,5 mm.

¹ To be published

INTRODUCTION

This part of IEC 62305 deals with the protection, in and around a structure, against physical damage and injury to living beings due to touch and step voltages.

The main and most effective measure for protection of structures against physical damage is considered to be the lightning protection system (LPS). It usually consists of both external and internal lightning protection systems.

An external LPS is intended to:

- a) intercept a lightning flash to the structure (with an air-termination system);
- b) conduct the lightning current safely towards earth (using a down-conductor system);
- c) disperse the lightning current into the earth (using an earth-termination system).

An internal LPS prevents dangerous sparking within the structure using either equipotential bonding or a separation distance (and hence electrical insulation) between the external LPS (as defined in 3.2) components and other electrically conducting elements internal to the structure.

Main protection measures against injury to living beings due to touch and step voltages are intended to:

- 1) reduce the dangerous current flowing through bodies by insulating exposed conductive parts, and/or by increasing the surface soil resistivity;
- 2) reduce the occurrence of dangerous touch and step voltages by physical restrictions and/or warning notices.

The type and location of an LPS should be carefully considered in the initial design of a new structure, thereby enabling maximum advantage to be taken of the electrically conductive parts of the structure. By doing so, design and construction of an integrated installation is made easier, the overall aesthetic aspects can be improved, and the effectiveness of the LPS can be increased at minimum cost and effort.

Access to the ground and the proper use of foundation steelwork for the purpose of forming an effective earth termination may well be impossible once construction work on a site has commenced. Therefore, soil resistivity and the nature of the earth should be considered at the earliest possible stage of a project. This information is fundamental to the design of an earth-termination system and may influence the foundation design work for the structure.

Regular consultation between LPS designers and installers, architects and builders is essential in order to achieve the best result at minimum cost.

If lightning protection is to be added to an existing structure, every effort should be made to ensure that it conforms to the principles of this standard. The design of the type and location of an LPS should take into account the features of the existing structure.

PROTECTION AGAINST LIGHTNING –

Part 3: Physical damage to structures and life hazard

1 Scope

This part of IEC 62305 provides the requirements for protection of a structure against physical damage by means of a lightning protection system (LPS), and for protection against injury to living beings due to touch and step voltages in the vicinity of an LPS (see IEC 62305-1).

This standard is applicable to:

- a) design, installation, inspection and maintenance of an LPS for structures without limitation of their height;
- b) establishment of measures for protection against injury to living beings due to touch and step voltages.

NOTE 1 Specific requirements for an LPS in structures dangerous to their surroundings due to the risk of explosion are under consideration. Additional information is provided in Annex D for use in the interim.

NOTE 2 This part of IEC 62305 is not intended to provide protection against failures of electrical and electronic systems due to overvoltages. Specific requirements for such cases are provided in IEC 62305-4.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60079-10:2002, *Electrical apparatus for explosive gas atmospheres – Part 10: Classification of hazardous areas*

IEC 60079-14:2002, *Electrical apparatus for explosive gas atmospheres – Part 14: Electrical installations in hazardous areas (other than mines)*

IEC 61241-10:2004, *Electrical apparatus for use in the presence of combustible dust – Part 10: Classification of areas where combustible dusts are or may be present*

IEC 61241-14:2004, *Electrical apparatus for use in the presence of combustible dust – Part 14: Selection and installation*

IEC 61643-12:2002, *Low-voltage surge protective devices – Part 12: Surge protective devices connected to low voltage power distribution systems – Selection and application principles*

IEC 62305-1, *Protection against lightning – Part 1: General principles*

IEC 62305-2, *Protection against lightning – Part 2: Risk management*

IEC 62305-4, *Protection against lightning – Part 4: Electrical and electronic systems within structures*

IEC 62305-5, *Protection against lightning – Part 5: Services*¹

ISO 3864-1, *Graphical symbols – Safety colours and safety signs – Part 1: Design principles for safety signs in workplaces and public areas*

3 Terms and definitions

For the purposes of this document, the following terms and definitions, some of which have already been cited in Part 1 but are repeated here for ease of reference, as well as those given in other parts of IEC 62305, apply.

3.1 lightning protection system LPS

complete system used to reduce physical damage due to lightning flashes to a structure

NOTE It consists of both external and internal lightning protection systems.

3.2 external lightning protection system

part of the LPS consisting of an air-termination system, a down-conductor system and an earth-termination system

3.3 external LPS isolated from the structure to be protected

LPS with an air-termination system and down-conductor system positioned in such a way that the path of the lightning current has no contact with the structure to be protected

NOTE In an isolated LPS, dangerous sparks between the LPS and the structure are avoided.

3.4 external LPS not isolated from the structure to be protected

LPS with an air-termination system and down-conductor system positioned in such a way that the path of the lightning current can be in contact with the structure to be protected

3.5 internal lightning protection system

part of the LPS consisting of lightning equipotential bonding and/or electrical insulation of external LPS

3.6 air-termination system

part of an external LPS using metallic elements such as rods, mesh conductors or catenary wires intended to intercept lightning flashes

3.7 down-conductor system

part of an external LPS intended to conduct lightning current from the air-termination system to the earth-termination system

¹ To be published

3.8**ring conductor**

conductor forming a loop around the structure and interconnecting the down-conductors for distribution of lightning current among them

3.9**earth-termination system**

part of an external LPS which is intended to conduct and disperse lightning current into the earth

3.10**earthing electrode**

part or a group of parts of the earth-termination system which provides direct electrical contact with the earth and disperses the lightning current into the earth

3.11**ring earthing electrode**

earthing electrode forming a closed loop around the structure below or on the surface of the earth

3.12**foundation earthing electrode**

reinforcing steel of foundation or additional conductor embedded in the concrete foundation of a structure and used as an earthing electrode

3.13**conventional earth impedance**

ratio of the peak values of the earth-termination voltage and the earth-termination current which, in general, do not occur simultaneously

3.14**earth-termination voltage**

potential difference between the earth-termination system and the remote earth

3.15**natural component of LPS**

conductive component installed not specifically for lightning protection which can be used in addition to the LPS or in some cases could provide the function of one or more parts of the LPS

NOTE Examples of the use of this term include:

- natural air-termination;
- natural down-conductor;
- natural earthing electrode.

3.16**connecting component**

part of an external LPS which is used for the connection of conductors to each other or to metallic installations

3.17**fixing component**

part of an external LPS which is used to fix the elements of the LPS to the structure to be protected

3.18**metal installations**

extended metal items in the structure to be protected which may form a path for lightning current, such as pipework, staircases, elevator guide rails, ventilation, heating and air-conditioning ducts, and interconnected reinforcing steel

3.19**external conductive parts**

extended metal items entering or leaving the structure to be protected such as pipework, metallic cable elements, metal ducts, etc. which may carry a part of the lightning current

3.20**electrical system**

system incorporating low voltage power supply components and possibly electronic components

3.21**electronic system**

system incorporating sensitive electronic components such as communication equipment, computer, control and instrumentation systems, radio systems, power electronic installations

3.22**internal systems**

electrical and electronic systems within a structure

3.23**lightning equipotential bonding****EB**

bonding to the LPS of separated conductive parts, by direct connections or via surge protective devices, to reduce potential differences caused by lightning current

3.24**bonding bar**

metal bar on which metal installations, external conductive parts, electric power and telecommunication lines, and other cables can be bonded to an LPS

3.25**bonding conductor**

conductor connecting separated conductive parts to LPS

3.26**interconnected reinforcing steel**

steelwork within a concrete structure which is considered electrically continuous

3.27**dangerous sparking**

electrical discharge due to lightning which causes physical damage in the structure to be protected

3.28**separation distance**

distance between two conductive parts at which no dangerous sparking can occur

3.29**surge protective device****SPD**

device that is intended to limit transient overvoltages and divert surge currents. It contains at least one non-linear component

3.30**test joint**

joint designed to facilitate electrical testing and measurement of LPS components

3.31**class of LPS**

number denoting the classification of an LPS according to the lightning protection level for which it is designed

3.32**lightning protection designer**

specialist competent and skilled in the design of the LPS

3.33**lightning protection installer**

person competent and skilled in the installation of the LPS

3.34**structures with risk of explosion**

structures containing solid explosives materials or hazardous zones as determined in accordance with IEC 60079-10 and IEC 61241-10

4 Lightning protection system (LPS)**4.1 Class of LPS**

The characteristics of an LPS are determined by the characteristics of the structure to be protected and by the considered lightning protection level.

Four classes of LPS (I to IV) are defined in this standard corresponding to lightning protection levels defined in IEC 62305-1 (see Table 1).

Table 1 – Relation between lightning protection levels (LPL) and class of LPS (see IEC 62305-1)

LPL	Class of LPS
I	I
II	II
III	III
IV	IV

Each class of LPS is characterized by the following.

a) Data dependent upon the class of LPS:

- lightning parameters (see Tables 3 and 4 in IEC 62305-1);
- rolling sphere radius, mesh size and protection angle (see 5.2.2);
- typical distances between down-conductors and between ring conductors (see 5.3.3);
- separation distance against dangerous sparking (see 6.3);
- minimum length of earth electrodes (see 5.4.2).

b) Data not dependent upon the class of LPS:

- lightning equipotential bonding (see 6.2);
- minimum thickness of metal sheets or metal pipes in air-termination systems (see 5.2.5);
- LPS materials and conditions of use (see 5.5);
- material, configuration and minimum dimensions for air-terminations, down-conductors and earth-terminations (see 5.6);
- minimum dimensions of connecting conductors (see 6.2.2).

Performance of each class of LPS is given in Annex B of IEC 62305-2.

The class of required LPS shall be selected on the basis of a risk assessment (see IEC 62305-2).

4.2 Design of the LPS

A technically and economically optimized design of an LPS is possible especially if the steps in the design and construction of the LPS are coordinated with the steps in the design and construction of the structure to be protected. In particular, the design of the structure itself should utilize the metal parts of the structure as parts of the LPS.

The design of the class and location of the LPS for existing structures shall take into account the constraints of the existing situation.

The design documentation of an LPS shall contain all the information necessary to ensure correct and complete installation. For detailed information, see Annex E.

4.3 Continuity of steelwork in reinforced concrete structures

Steelwork within reinforced concrete structures is considered to be electrically continuous provided that the major part of interconnections of vertical and horizontal bars are welded or otherwise securely connected. Connections of vertical bars shall be welded, clamped or overlapped a minimum of 20 times their diameters and bound or otherwise securely connected. For new structures, the connections between reinforcement elements shall be specified by the designer or installer, in cooperation with the builder and the civil engineer.

For structures utilizing steel reinforced concrete (including pre-cast, pre-stressed reinforced units), the electrical continuity of the reinforcing bars shall be determined by electrical testing between the uppermost part and ground level. The overall electrical resistance should not be greater than 0,2 Ω , measured using test equipment suitable for this purpose. If this value is not achieved, or it is not practical to conduct such testing, the reinforcing steel shall not be used as a natural down-conductor as discussed in 5.3.5. In this case it is recommended that an external down-conductor be installed: In the case of structures of pre-cast reinforced concrete, the electrical continuity of the reinforcing steel shall be established between individual adjacent pre-cast concrete units.

NOTE 1 For further information on the continuity of steelwork in reinforced concrete structures, see Annex E.

NOTE 2 In several countries, the use of reinforced concrete as a part of the LPS is not allowed.

5 External lightning protection system

5.1 General

5.1.1 Application of an external LPS

The external LPS is intended to intercept direct lightning flashes to the structure, including flashes to the side of the structure, and conduct the lightning current from the point of strike to ground. The external LPS is also intended to disperse this current into the earth without causing thermal or mechanical damage, nor dangerous sparking which may trigger fire or explosions.

5.1.2 Choice of external LPS

In most cases, the external LPS may be attached to the structure to be protected.

An isolated external LPS should be considered when the thermal and explosive effects at the point of strike, or on the conductors carrying the lightning current, may cause damage to the structure or to the contents (see Annex E). Typical examples include structures with combustible covering, structures with combustible walls and areas at risk of explosion and fire.

NOTE The use of an isolated LPS may be convenient where it is predicted that changes in the structure, its contents or its use will require modifications to the LPS.

An isolated external LPS may also be considered when the susceptibility of the contents warrants the reduction of the radiated electromagnetic field associated with the lightning current pulse in the down-conductor.

5.1.3 Use of natural components

Natural components made of conductive materials, which will always remain in/on the structure and will not be modified (e.g. interconnected reinforced steel, metal framework of the structure, etc.) may be used as parts of an LPS.

Other natural components should be considered as being additional to an LPS.

NOTE For further information, see Annex E.

5.2 Air-termination systems

5.2.1 General

The probability of structure penetration by a lightning current is considerably decreased by the presence of a properly designed air-termination system.

Air-termination systems can be composed of any combination of the following elements:

- a) rods (including free-standing masts);
- b) catenary wires;
- c) meshed conductors.

To conform to this standard, all types of air-termination systems shall be positioned in accordance with 5.2.2, 5.2.3 and Annex A.

The individual air-termination rods should be connected together at roof level to ensure current division.

Radioactive air terminals are not allowed.

5.2.2 Positioning

Air-termination components installed on a structure shall be located at corners, exposed points and edges (especially on the upper level of any facades) in accordance with one or more of the following methods.

Acceptable methods to be used in determining the position of the air-termination system include:

- the protection angle method;
- the rolling sphere method;
- the mesh method.

The rolling sphere method is suitable in all cases.

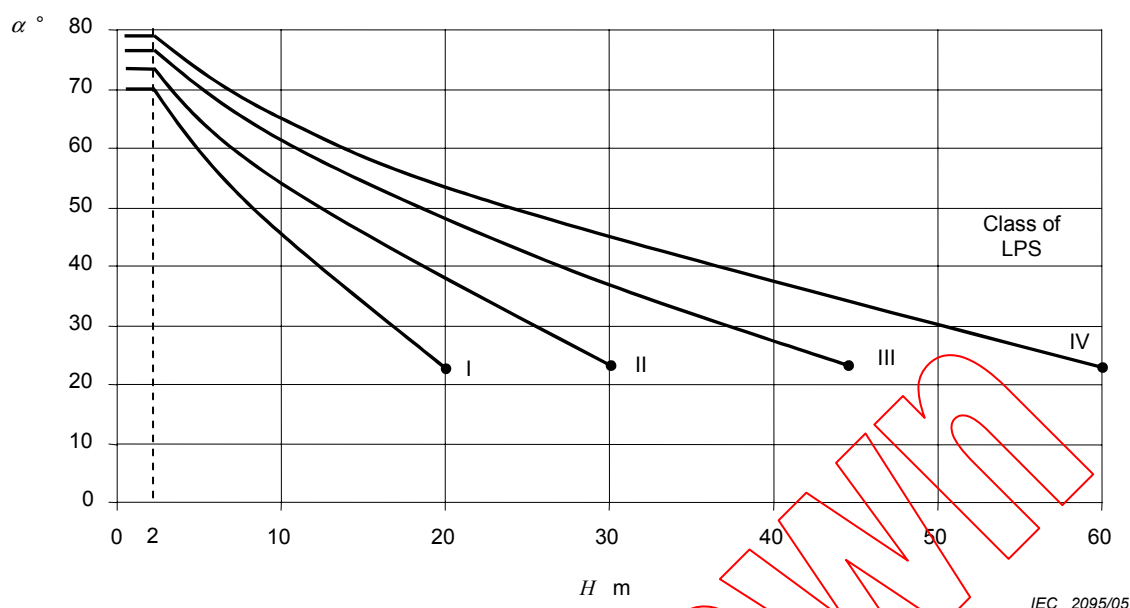
The protection angle method is suitable for simple-shaped buildings but it is subject to limits of air-termination height indicated in Table 2.

The mesh method is a suitable form of protection where plane surfaces are to be protected.

The values for the protection angle, rolling sphere radius and mesh size for each class of LPS are given in Table 2. Detailed information on the positioning of the air-termination system is given in Annex A.

Table 2 – Maximum values of rolling sphere radius, mesh size and protection angle corresponding to the class of LPS

Class of LPS	Protection method		
	Rolling sphere radius r m	Mesh size W m	Protection angle α°
I	20	5 × 5	See figure below
II	30	10 × 10	
III	45	15 × 15	
IV	60	20 × 20	



NOTE 1 Not applicable beyond the values marked with •.
Only rolling sphere and mesh methods apply in these cases.

NOTE 2 H is the height of air-termination above the reference plane of the area to be protected.

NOTE 3 The angle will not change for values of H below 2 m.

5.2.3 Air-terminations against flashes to the side of tall structures

On structures taller than 60 m, flashes to the side may occur, especially to points, corners and edges of surfaces.

NOTE In general the risk due to these flashes is low because only a few per cent of all flashes to tall structures will be to the side and moreover their parameters are significantly lower than those of flashes to the top of structures. However, electrical and electronic equipment on walls outside structures may be destroyed even by lightning flashes with low current peak values.

An air-termination system shall be installed to protect the upper part of tall structures (i.e. typically the topmost 20 % of the height of the structure) and the equipment installed on it (see Annex A).

The rules for positioning air-termination systems on roofs shall also apply to those upper parts of structures.

In addition, for structures taller than 120 m, all parts which may be endangered above 120 m should be protected.

5.2.4 Construction

Air-terminations of an LPS not isolated from the structure to be protected may be installed as follows:

- if the roof is made of non-combustible material the air-termination conductors may be positioned on the surface of the roof;
- if the roof is made of readily-combustible material, due care needs to be taken with regard to the distance between the air-termination conductors and the material. For thatched roofs where no steel bars are used for monitoring of the reed, a distance of 0,15 m is adequate. For other combustible materials a distance not lower than 0,10 m is considered adequate;

- Easily-combustible parts of the structure to be protected shall not remain in direct contact with the components of an external LPS and shall not remain directly under any metallic roofing membrane that might be punctured by a lightning flash (see 5.2.5).

Account shall also be taken of less combustible membranes such as wooden sheets.

NOTE If it is likely that water may accumulate on a flat roof, air-terminations should be installed above the maximum probable water level.

5.2.5 Natural components

The following parts of a structure should be considered as natural air-termination components and part of an LPS in accordance with 5.1.3.

- a) Metal sheets covering the structure to be protected provided that:
- the electrical continuity between the various parts is made durable (e.g. by means of brazing, welding, crimping, seaming, screwing or bolting);
 - the thickness of the metal sheet is not less than the value t' given in Table 3 if it is not important to prevent puncture of the sheeting or to consider ignition of any readily-combustible materials underneath;
 - the thickness of the metal sheet is not less than the value t given in Table 3 if it is necessary to take precautions against puncture or to consider hot spot problems;
 - they are not clad with insulating material.

Table 3 – Minimum thickness of metal sheets or metal pipes in air-termination systems

Class of LPS	Material	Thickness ^a t mm	Thickness ^b t' mm
I to IV	Lead	–	2,0
	Steel (stainless, galvanized)	4	0,5
	Titanium	4	0,5
	Copper	5	0,5
	Aluminium	7	0,65
	Zinc	–	0,7
^a t prevents puncture, hot spot or ignition. ^b t' only for metal sheets if it is not important to prevent puncture, hot spot or ignition problems.			

- b) Metal components of roof construction (trusses, interconnected reinforcing steel, etc.), underneath non-metallic roofing, provided that this latter part can be excluded from the structure to be protected.
- c) Metal parts such as ornamentation, railings, pipes, coverings of parapets, etc., with cross-sections not less than that specified for standard air-termination components.
- d) Metal pipes and tanks on the roof, provided that they are constructed of material with thicknesses and cross-sections in accordance with Table 6.
- e) Metal pipes and tanks carrying readily-combustible or explosive mixtures, provided that they are constructed of material with thickness not less than the appropriate value of t given in Table 3 and that the temperature rise of the inner surface at the point of strike does not constitute a danger (for detailed information, see Annex E).

If the conditions for thickness are not fulfilled, the pipes and tanks shall be integrated into the structure to be protected.

Piping carrying readily-combustible or explosive mixtures shall not be considered as an air-termination natural component if the gasket in the flange couplings is not metallic or if the flange-sides are not otherwise properly bonded.

NOTE A thin coating of protective paint or about 1 mm asphalt or 0,5 mm PVC is not regarded as an insulator. Detailed information is given in Annex E.

5.3 Down-conductor systems

5.3.1 General

In order to reduce the probability of damage due to lightning current flowing in the LPS, the down-conductors shall be arranged in such a way that from the point of strike to earth.

- a) several parallel current paths exist;
- b) the length of the current paths is kept to a minimum;
- c) equipotential bonding to conducting parts of the structure is performed according to the requirements of 6.2.

NOTE 1 Lateral connection of down-conductors at ground level and every 10 m to 20 m of height, in accordance with Table 4, is considered to be good practice.

The geometry of the down-conductors and of the ring conductors affects the separation distance (see 6.3).

NOTE 2 The installation of as many down-conductors as possible, at equal spacing around the perimeter interconnected by ring conductors, reduces the probability of dangerous sparking and facilitates the protection of internal installations (see IEC 62305-4). This condition is fulfilled in metal framework structures and in reinforced concrete structures in which the interconnected steel is electrically continuous.

Typical values of the distance between down-conductors and between horizontal ring conductors are given in Table 4.

More information on partitioning of the lightning current amongst down-conductors is given in Annex C.

5.3.2 Positioning for an isolated LPS

- a) If the air-termination consists of rods on separate masts (or one mast) not made of metal or interconnected reinforcing steel, at least one down-conductor is needed for each mast. No additional down-conductors are required for masts made of metal or interconnected reinforcing steel.

NOTE In several countries, the use of reinforced concrete as a part of the LPS is not allowed.

- b) If the air-termination consists of catenary wires (or one wire), at least one down-conductor is needed at each supporting structure.
- c) If the air-termination forms a network of conductors, one down-conductor is needed at least at each supporting wire end.

5.3.3 Positioning for a non-isolated LPS

For each non-isolated LPS the number of down-conductors shall be not less than two and should be distributed around the perimeter of the structure to be protected, subject to architectural and practical constraints.

An equal spacing of the down-conductors is preferred around the perimeter. Typical values of the distance between down-conductors are given in Table 4.

NOTE The value of the distance between down-conductors is correlated with the separation distance given in 6.3.

Table 4 – Typical values of the distance between down-conductors and between ring conductors according to the class of LPS

Class of LPS	Typical distances m
I	10
II	10
III	15
IV	20

A down-conductor should be installed at each exposed corner of the structure, where this is possible.

5.3.4 Construction

The down-conductors shall be installed so that, as far as practicable, they form a direct continuation of the air-termination conductors.

Down-conductors shall be installed straight and vertical such that they provide the shortest and most direct path to earth. The formation of loops shall be avoided, but where this is not possible, the distance s , measured across the gap between two points on the conductor and the length l of the conductor between those points (see Figure 1) shall conform to 6.3.

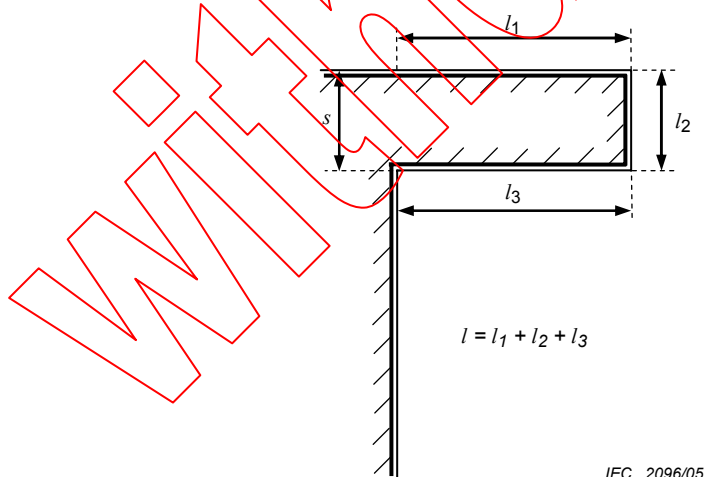


Figure 1 – Loop in a down-conductor

Down-conductors shall not be installed in gutters or down-spouts even if they are covered by insulating material.

NOTE The effects of moisture in the gutters lead to intensive corrosion of the down-conductor. It is recommended that the down-conductors be positioned such that a separation distance in accordance with 6.3 is provided between them and any doors and windows.

Down-conductors of an LPS not isolated from the structure to be protected may be installed as follows:

- if the wall is made of non-combustible material, the down-conductors may be positioned on the surface or in the wall;
- if the wall is made of readily-combustible material the down-conductors may be positioned on the surface of the wall, provided that their temperature rise due to the passage of lightning current is not dangerous for the material of the wall;
- if the wall is made of readily-combustible material and the temperature rise of down-conductors is dangerous, the down-conductors shall be placed in such a way that the distance between them and the wall is always greater than 0,1 m. Mounting brackets may be in contact with the wall.

When the distance from down-conductor to a combustible material cannot be assured, the cross-section of the conductor shall be not less than 100 mm².

5.3.5 Natural components

The following parts of the structure should be considered as natural down-conductors:

- a) the metal installations provided that
- the electrical continuity between the various parts is made durable in accordance with 5.5.2,
 - their dimensions are at least equal to that specified in Table 6 for standard down-conductors.

Piping carrying readily-combustible or explosive mixtures shall not be considered as a down-conductor natural component if the gasket in the flange couplings is not metallic or if the flange-sides are not otherwise properly bonded.

NOTE 1 Metal installations may be clad with insulating material.

- b) the metal of the electrically-continuous reinforced concrete framework of the structure;

NOTE 2 With prefabricated reinforced concrete, it is important to establish interconnection points between the reinforcing elements. It is also important that reinforced concrete contains a conductive connection between the interconnection points. The individual parts should be connected on-site during assembly (see Annex E).

NOTE 3 In the case of pre-stressed concrete, attention should be paid to the risk of causing unacceptable mechanical consequences, due either to lightning current or as a result of the connection to the lightning protection system.

- c) the interconnected steel framework of the structure;

NOTE 4 Ring conductors are not necessary if the metal framework of steel structures or the interconnected reinforcing steel of the structure is used as down-conductors.

- d) the facade elements, profile rails and metallic sub-constructions of facades, provided that
- their dimensions conform to the requirements for down-conductors (see 5.6.2) and that for metal sheets or metal pipes thicknesses shall be not less than 0,5 mm,
 - their electrical continuity in a vertical direction conforms to the requirements of 5.5.2.

NOTE 5 For more information, see Annex E.

5.3.6 Test joints

At the connection of the earth termination, a test joint should be fitted on each down-conductor, except in the case of natural down-conductors combined with foundation earth electrodes.

For measuring purposes, the joint shall be capable of being opened with the aid of a tool. In normal use it shall remain closed.

5.4 Earth-termination system

5.4.1 General

When dealing with the dispersion of the lightning current (high frequency behaviour) into the ground, whilst minimizing any potentially dangerous overvoltages, the shape and dimensions of the earth-termination system are the important criteria. In general, a low earthing resistance (if possible lower than 10 Ω when measured at low frequency) is recommended.

From the viewpoint of lightning protection, a single integrated structure earth-termination system is preferable and is suitable for all purposes (i.e. lightning protection, power systems and telecommunication systems).

Earth-termination systems shall be bonded in accordance with the requirements of 6.2.

NOTE 1 The conditions of separation and bonding of other earth-termination systems are usually determined by the appropriate national authorities.

NOTE 2 Serious corrosion problems can occur when earthing systems made of different materials are connected to each other.

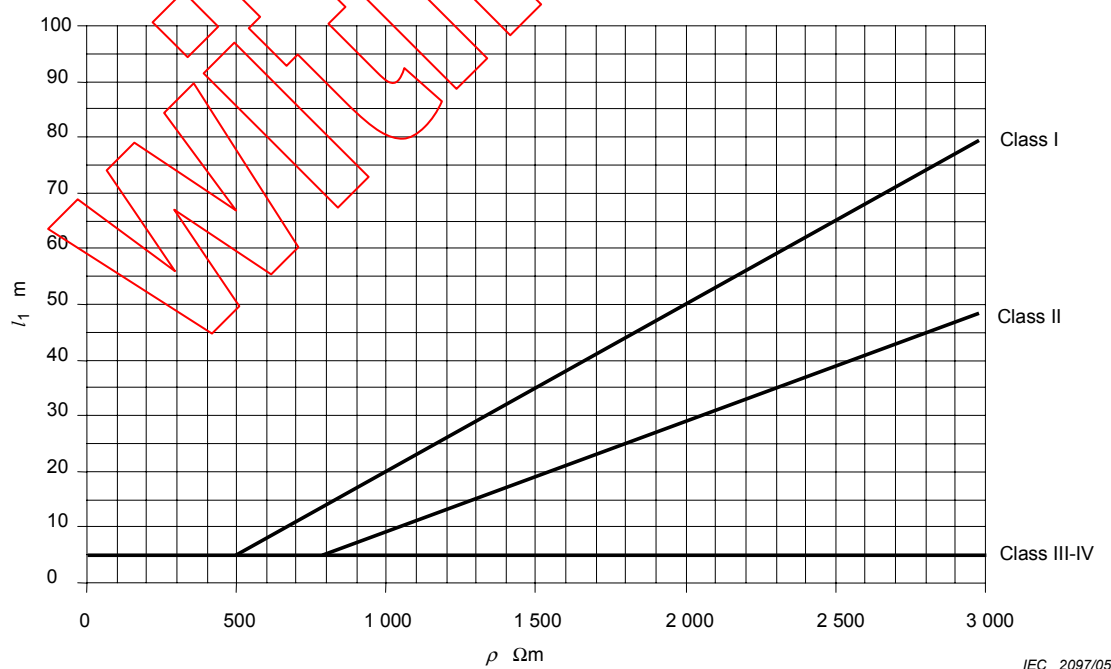
5.4.2 Earthing arrangement in general conditions

For earth-termination systems, two basic types of earth electrode arrangements apply.

5.4.2.1 Type A arrangement

This type of arrangement comprises horizontal or vertical earth electrodes installed outside the structure to be protected connected to each down-conductor.

In type A arrangements, the total number of earth electrodes shall be not less than two.



NOTE Classes III and IV are independent of soil resistivity.

Figure 2 – Minimum length l_1 of each earth electrode according to the class of LPS

The minimum length of each earth electrode at the base of each down-conductor is

- l_1 for horizontal electrodes, or
- $0,5 l_1$ for vertical (or inclined) electrodes,

where l_1 is the minimum length of horizontal electrodes shown in the relevant part of Figure 2.

For combined (vertical or horizontal) electrodes, the total length shall be considered.

The minimum lengths stated in Figure 2 may be disregarded provided that an earthing resistance of the earth-termination system less than 10Ω (measured at a frequency different from the power frequency and its multiple in order to avoid interference) is achieved.

NOTE 1 Reduction of earthing resistance by the extension of earth electrodes is practically possible up to 60 m.

NOTE 2 For further information, refer to Annex E.

5.4.2.2 Type B arrangement

This type of arrangement comprises either a ring conductor external to the structure to be protected, in contact with the soil for at least 80 % of its total length, or a foundation earth electrode. Such earth electrodes may also be meshed.

For the ring earth electrode (or foundation earth electrode), the mean radius r_e of the area enclosed by the ring earth electrode (or foundation earth electrode) shall be not less than the value l_1 :

$$r_e \geq l_1 \quad (1)$$

where l_1 is represented in Figure 2 according to LPS class I, II, III and IV.

When the required value of l_1 is larger than the convenient value of r_e , additional horizontal or vertical (or inclined) electrodes shall be added with individual lengths l_r (horizontal) and l_v (vertical) given by the following equations:

$$l_r = l_1 - r_e \quad (2)$$

and
$$l_v = (l_1 - r_e)/2 \quad (3)$$

It is recommended that the number of electrodes shall be not less than the number of the down-conductors, with a minimum of two.

The additional electrodes should be connected to the ring earth electrode at points where the down-conductors are connected and, for as many as possible, equidistantly.

5.4.3 Installation of earth electrodes

The ring earth electrode (type B arrangement) should preferably be buried at a depth of at least 0,5 m and at a distance of about 1 m around the external walls.

The earth electrodes (type A arrangement) shall be installed at a depth of upper end at least 0,5 m and distributed as uniformly as possible to minimize electrical coupling effects in the earth.

Earth electrodes shall be installed in such a way as to allow inspection during construction.

The embedded depth and the type of earth electrodes shall be such as to minimize the effects of corrosion, soil drying and freezing and thereby stabilize the conventional earth resistance. It is recommended that the upper part of a vertical earth electrode equal to the depth of freezing soil should not be regarded as being effective under frost conditions.

NOTE Hence, for every vertical electrode, 0,5 m should be added to the value of the length l_1 , calculated in 5.4.2.1 and 5.4.2.2.

For bare solid rock, only type B earthing arrangement is recommended.

For structures with extensive electronic systems or with high risk of fire (see IEC 62305-2), type B earthing arrangement is preferable.

5.4.4 Natural earth electrodes

Interconnected reinforcing steel in concrete foundations in accordance with 5.6, or other suitable underground metal structures, should preferably be used as an earth electrode. When the metallic reinforcement in concrete is used as an earth electrode, special care shall be exercised at the interconnections to prevent mechanical splitting of the concrete.

NOTE 1 In the case of pre-stressed concrete, consideration should be given to the consequences of the passage of lightning discharge currents which may produce unacceptable mechanical stresses.

NOTE 2 If a foundation earth electrode is used, a long-term increase in earthing resistance is possible.

NOTE 3 More extensive information on this topic is reported in Annex E.

5.5 Components

Components of an LPS shall withstand the electromagnetic effects of lightning current and predictable accidental stresses without being damaged.

Components of an LPS shall be manufactured from the materials listed in Table 5 or from other materials with equivalent mechanical, electrical and chemical (corrosion) performance characteristics.

NOTE Components made of material other than metal may be used for fixing.

Table 5 – LPS materials and conditions of use

Material	Use			Corrosion		
	In open air	In earth	In concrete	Resistance	Increased by	May be destroyed by galvanic coupling with
Copper	Solid Stranded	Solid Stranded As coating	Solid Stranded As coating	Good in many environments	Sulphur compounds Organic materials	–
Hot galvanized steel	Solid Stranded	Solid	Solid Stranded	Acceptable in air, in concrete and in benign soil	High chlorides content	Copper
Stainless steel	Solid Stranded	Solid Stranded	Solid Stranded	Good in many environments	High chlorides content	–
Aluminium	Solid Stranded	Unsuitable	Unsuitable	Good in atmospheres containing low concentrations of sulphur and chloride	Alkaline solutions	Copper
Lead	Solid As coating	Solid As Coating	Unsuitable	Good in atmosphere with high concentration of sulphates	Acid soils	Copper Stainless steel
NOTE 1 This table gives general guidance only. In special circumstances more careful corrosion immunity considerations are required (see Annex E). NOTE 2 Stranded conductors are more vulnerable to corrosion than solid conductors. Stranded conductors are also vulnerable where they enter or exit earth/concrete positions. This is the reason why stranded galvanized steel is not recommended in earth. NOTE 3 Galvanized steel may be corroded in clay soil or moist soil. NOTE 4 Galvanized steel in concrete should not extend into the soil due to possible corrosion of the steel just outside the concrete. NOTE 5 Galvanized steel in contact with reinforcement steel in concrete may, under certain circumstances, cause damage to the concrete. NOTE 6 Use of lead in the earth is often banned or restricted due to environmental concerns.						

5.5.1 Fixing

Air-terminations and down-conductors shall be firmly fixed so that the electrodynamic or accidental mechanical forces (for instance vibrations, slipping of slabs of snow, thermal expansion, etc.) will not cause conductors to break or loosen (see Annex D of IEC 62305-1).

5.5.2 Connections

The number of connections along the conductors shall be kept to a minimum. Connections shall be made secure by such means as brazing, welding, clamping, crimping, seaming, screwing or bolting.

Connections of steelwork within reinforced concrete structures shall conform to 4.3.

5.6 Materials and dimensions

5.6.1 Materials

Material and its dimensions shall be chosen bearing in mind the possibility of corrosion either of the structure to be protected or of the LPS.

5.6.2 Dimensions

Configurations and minimum cross-sectional areas of air-termination conductors, air-termination rods and down-conductors are given in Table 6.

Configurations and minimum dimensions of earth electrodes are given in Table 7.

Withdrawn

Table 6 – Material, configuration and minimum cross-sectional area of air-termination conductors, air-termination rods and down-conductors

Material	Configuration	Minimum cross-sectional area mm ²	Comments ¹⁰⁾
Copper	Solid tape	50 ⁸⁾	2 mm min. thickness
	Solid round ⁷⁾	50 ⁸⁾	8 mm diameter
	Stranded	50 ⁸⁾	1,7 mm min. diameter of each strand
	Solid round ^{3), 4)}	200 ⁸⁾	16 mm diameter
Tin plated copper ¹⁾	Solid tape	50 ⁸⁾	2 mm min. thickness
	Solid round ⁷⁾	50 ⁸⁾	8 mm diameter
	Stranded	50 ⁸⁾	1,7 mm min. diameter of each strand
Aluminium	Solid tape	70	3 mm min. thickness
	Solid round	50 ⁸⁾	8 mm diameter
	Stranded	50 ⁸⁾	1,7 mm min. diameter of each strand
Aluminium alloy	Solid tape	50 ⁸⁾	2,5 mm min. thickness
	Solid round	50	8 mm diameter
	Stranded	50 ⁸⁾	1,7 mm min. diameter of each strand
	Solid round ³⁾	200 ⁸⁾	16 mm diameter
Hot dipped galvanized steel ²⁾	Solid tape	50 ⁸⁾	2,5 mm min. thickness
	Solid round ⁹⁾	50	8 mm diameter
	Stranded	50 ⁸⁾	1,7 mm min. diameter of each strand
	Solid round ^{3), 4), 9)}	200 ⁸⁾	16 mm diameter
Stainless steel ⁵⁾	Solid tape ⁶⁾	50 ⁸⁾	2 mm min. thickness
	Solid round ⁶⁾	50	8 mm diameter
	Stranded	70 ⁸⁾	1,7 mm min. diameter of each strand
	Solid round ^{3), 4)}	200 ⁸⁾	16 mm diameter
1) Hot dipped or electroplated minimum thickness coating of 1 µm. 2) The coating should be smooth, continuous and free from flux stains with a minimum thickness coating of 50 µm. 3) Applicable for air-termination rods only. For applications where mechanical stress such as wind loading is not critical, a 10 mm diameter, 1 m long maximum air-termination rod with an additional fixing may be used. 4) Applicable to earth lead-in rods only. 5) Chromium ≥ 16 %, nickel ≥ 8 %, carbon ≤ 0,07 %. 6) For stainless steel embedded in concrete, and/or in direct contact with flammable material, the minimum sizes should be increased to 78 mm² (10 mm diameter) for solid round and 75 mm² (3 mm minimum thickness) for solid tape. 7) 50 mm² (8 mm diameter) may be reduced to 28 mm² (6 mm diameter) in certain applications where mechanical strength is not an essential requirement. Consideration should, in this case, be given to reducing the spacing of the fasteners. 8) If thermal and mechanical considerations are important, these dimensions can be increased to 60 mm² for solid tape and to 78 mm² for solid round. 9) The minimum cross-section to avoid melting is 16 mm² (copper), 25 mm² (aluminium), 50 mm² (steel) and 50 mm² (stainless steel) for a specific energy of 10 000 kJ/Ω. For further information see Annex E. 10) Thickness, width and diameter are defined at ±10 %.			

Table 7 – Material, configuration and minimum dimensions of earth electrodes

Material	Configuration	Minimum dimensions			Comments
		Earth rod Ø mm	Earth conductor	Earth plate mm	
Copper	Stranded ³⁾		50 mm ²		1,7 mm min. diameter of each strand
	Solid round ³⁾		50 mm ²		8 mm diameter
	Solid tape ³⁾		50 mm ²		2 mm min. thickness
	Solid round	15 ⁸⁾			
	Pipe	20			2 mm min. wall thickness
	Solid plate			500 x 500	2 mm min. thickness
	Lattice plate			600 x 600	25 mm x 2 mm section Minimum length of lattice configuration: 4,8 m
Steel	Galvanized solid round ^{1) 2)}	16 ⁹⁾	10 mm diameter		
	Galvanized pipe ^{1) 2)}	25			2 mm min. wall thickness
	Galvanized solid tape ¹⁾		90 mm ²		3 mm min. thickness
	Galvanized solid plate ¹⁾			500 x 500	3 mm min. thickness
	Galvanized lattice plate ¹⁾			600 x 600	30 mm x 3 mm section
	Copper coated solid round ⁴⁾	14			250 µm minimum radial Copper coating 99,9 % copper content
	Bare solid round ⁵⁾		10 mm diameter		
	Bare or galvanized solid tape ^{5) 6)}		75 mm ²		3 mm min. thickness
	Galvanized stranded ^{5) 6)}		70 mm ²		1,7 mm min. diameter of each strand
	Galvanized cross profile ¹⁾	50 x 50 x 3			
Stainless steel ⁷⁾	Solid round	15	10 mm diameter		
	Solid tape		100 mm ²		2 mm min. thick

1) The coating shall be smooth, continuous and free from flux stains with a minimum thickness of 50 µm for round and 70 µm for flat material.

2) Threads shall be machined prior to galvanizing.

3) May also be tin-plated.

4) The copper should be intrinsically bonded to the steel.

5) Only allowed when completely embedded in concrete.

6) Only allowed when correctly connected together at least every 5 m with the natural reinforcement steel of the earth touching part of the foundation.

7) Chromium ≥ 16 %, nickel ≥ 5 %, molybdenum ≥ 2 %, carbon ≤ 0,08 %.

8) In some countries 12 mm is allowed.

9) Earth lead in rods are used in some countries to connect the down-conductor to the point where it enters the ground.

6 Internal lightning protection system

6.1 General

The internal LPS shall avoid the occurrence of dangerous sparking within the structure to be protected due to lightning current flowing in the external LPS or in other conductive parts of the structure.

Dangerous sparking may occur between the external LPS and other components such as:

- the metal installations;
- the internal systems;
- the external conductive parts and lines connected to the structure.

NOTE 1 Sparking occurring within the structure with danger of explosion is always dangerous. In this case additional protective measures are required which are under consideration (see Annex E).

NOTE 2 For protection against overvoltages of internal systems, refer to IEC 62305-4.

Dangerous sparking between different parts can be avoided by means of

- equipotential bonding in accordance with 6.2, or
- electrical insulation between the parts in accordance with 6.3.

6.2 Lightning equipotential bonding

6.2.1 General

Equipotentialization is achieved by interconnecting the LPS with

- structural metal parts,
- metal installations,
- internal systems,
- external conductive parts and lines connected to the structure.

When lightning equipotential bonding is established to internal systems, part of the lightning current may flow into such systems and this effect shall be taken into account.

Interconnecting means can be

- bonding conductors, where the electrical continuity is not provided by natural bonding,
- surge protective devices (SPDs), where direct connections with bonding conductors is not feasible.

The manner in which lightning equipotential bonding is achieved is important and shall be discussed with the operator of the telecommunication network, the electric power operator, and other operators or authorities concerned, as there may be conflicting requirements.

SPDs shall be installed in such a way that they can be inspected.

NOTE When an LPS is installed, metalwork external to the structure to be protected may be affected. This should be considered when designing such systems. Lightning equipotential bonding for external metalwork may also be necessary.

6.2.2 Lightning equipotential bonding for metal installations

In the case of an isolated external LPS, lightning equipotential bonding shall be established at ground level only.

For an external LPS which is not isolated, lightning equipotential bonding shall be installed at the following locations:

- a) in the basement or approximately at ground level. Bonding conductors shall be connected to a bonding bar constructed and installed in such a way that it allows easy access for inspection. The bonding bar shall be connected to the earth-termination system. For large structures (typically more than 20 m in length), more than one bonding bar can be installed, provided that they are interconnected;
- b) where insulation requirements are not fulfilled (see 6.3).

Lightning equipotential bonding connections shall be made as direct and straight as possible.

NOTE When lightning equipotential bonding is established to conducting parts of the structure, part of the lightning current may flow into the structure and this effect should be taken into account.

The minimum values of the cross-section of the bonding conductors connecting different bonding bars and of the conductors connecting the bars to the earth-termination system are listed in Table 8.

The minimum values of the cross-section of the bonding conductors connecting internal metal installations to the bonding bars are listed in Table 9.

Table 8 – Minimum dimensions of conductors connecting different bonding bars or connecting bonding bars to the earth-termination system

Class of LPS	Material	Cross-section mm ²
I to IV	Copper	14
	Aluminium	22
	Steel	50

Table 9 – Minimum dimensions of conductors connecting internal metal installations to the bonding bar

Class of LPS	Material	Cross-section mm ²
I to IV	Copper	5
	Aluminium	8
	Steel	16

If insulating pieces are inserted into gas lines or water pipes, inside the structure to be protected they shall, with the agreement of the water and gas supplier, be bridged by SPDs designed for such an operation.

SPDs shall have the following characteristics:

- class I test;
- $I_{\text{imp}} \geq k_c I$ with $k_c I$ being the lightning current flowing along the relevant part of the external LPS (see Annex C);

- the protection level U_P shall be lower than the impulse withstand level of insulation between parts;
- other characteristics conforming to IEC 61643-12.

6.2.3 Lightning equipotential bonding for external conductive parts

For external conductive parts, lightning equipotential bonding shall be established as near as possible to the point of entry into the structure to be protected.

Bonding conductors shall be capable of withstanding the part I_f of the lightning current flowing through them evaluated in accordance with Annex E of IEC 62305-1.

If direct bonding is not acceptable, SPDs with the following characteristics shall be used:

- class I test;
- $I_{imp} \geq I_f$ with I_f being the lightning current flowing along the considered external conductive part (see Annex E of IEC 62305-1);
- the protection level U_P shall be lower than the impulse withstand level of insulation between parts;
- other characteristics conforming to IEC 61643-12.

NOTE When equipotential bonding is required, but an LPS is not required, the earth-termination of the low voltage electrical installation can be used for this purpose. IEC 62305-2 provides information on the conditions where an LPS is not required.

6.2.4 Lightning equipotential bonding for internal systems

It is imperative that lightning equipotential bonding is installed in accordance with 6.2.2 a) and 6.2.2 b).

If the internal systems conductors are screened or located in metal conduits, it may be sufficient to bond only these screens and conduits (see Annex B).

NOTE Bonding of screens and conduits may not avoid failure due to overvoltages of equipment connected to the conductors. For protection of such equipment refer to IEC 62305-4.

If conductors of internal systems are neither screened nor located in metal conduits, they shall be bonded via SPDs. In TN systems, PE and PEN conductors shall be bonded to the LPS directly or with a SPD.

Bonding conductors and SPDs shall have the same characteristics as indicated in 6.2.2.

If protection of internal systems against surges is required, a “coordinated SPD protection” conforming to the requirements of IEC 62305-4, Clause 7 shall be used.

6.2.5 Lightning equipotential bonding for lines connected to the structure to be protected

Lightning equipotential bonding for electrical and telecommunication lines shall be installed in accordance with 6.2.3.

All the conductors of each line should be bonded directly or with an SPD. Live conductors shall only be bonded to the bonding bar via an SPD. In TN systems, PE or PEN conductors shall be bonded directly or via SPD to the bonding bar.

If lines are screened or routed into metal conduits, these screens and conduits shall be bonded; lightning equipotential bonding for conductors is not necessary provided that the cross-section S_c of these screens or conduits is not lower than the minimum value S_{cmin} evaluated in accordance with Annex B.

Lightning equipotential bonding of the cable screens or of the conduits shall be performed near the point where they enter the structure.

Bonding conductors and SPDs shall have the same characteristics as indicated in 6.2.3.

If protection against surges of internal systems connected to lines entering the structure is required, a “coordinated SPD protection” conforming to the requirements of IEC 62305-4, Clause 7 shall be used.

NOTE 1 When equipotential bonding is required, but an LPS is not required, the earth-termination of the low voltage electrical installation can be used for this purpose. IEC 62305-2 provides information on the conditions where an LPS is not required.

NOTE 2 For more information concerning equipotential bonding for telecommunication lines, see also IEC 62305-5.

6.3 Electrical insulation of the external LPS

The electrical insulation between the air-termination or the down-conductor and the structural metal parts, the metal installations and the internal systems can be achieved by providing a distance d between the parts greater than the separation distance s :

$$s = k_i \frac{k_c}{k_m} l \quad (4)$$

where

- k_i depends on the selected class of LPS (see Table 10);
- k_c depends on the lightning current flowing on the down-conductors (see Table 11);
- k_m depends on the electrical insulation material (see Table 12);
- l is the length, in metres, along the air-termination or the down-conductor, from the point where the separation distance is to be considered, to the nearest equipotential bonding point.

Table 10 – Isolation of external LPS – Values of coefficient k_i

Class of LPS	k_i
I	0,08
II	0,06
III and IV	0,04

Table 11 – Isolation of external LPS – Values of coefficient k_c

Number of down-conductors n	Detailed values (see Table C.1) k_c
1	1
2	1 ... 0,5
4 and more	1 ... 1/ n

Table 12 – Isolation of external LPS – Values of coefficient k_m

Material	k_m
Air	1
Concrete, bricks	0,5
NOTE 1 When there are several insulating materials in series, it is good practice to use the lower value for k_m .	
NOTE 2 The use of other insulating materials is under consideration.	

In the case of the lines or external conductive parts connected to the structure, it is always necessary to ensure lightning equipotential bonding (by direct connection or connection by SPD) at their point of entry in the structure.

In structures with metallic or electrically continuous, connected, reinforced, concrete framework of the structures, a separation distance is not required.

7 Maintenance and inspection of an LPS

7.1 Application of inspections

The objective of the inspections is to ascertain that

- the LPS conforms to the design based on this standard,
- all components of the LPS are in good condition and capable of performing their designed functions, and that there is no corrosion,
- any recently added services or constructions are incorporated into the LPS.

7.2 Order of inspections

Inspections should be made according to 7.1 as follows:

- during the construction of the structure, in order to check the embedded electrodes;
- after the installation of the LPS;
- periodically at such intervals as determined with regard to the nature of the structure to be protected, i.e. corrosion problems and the class of LPS;

NOTE For detailed information see Clause E.7.

- after alterations or repairs, or when it is known that the structure has been struck by lightning.

During the periodic inspection, it is particularly important to check the following:

- deterioration and corrosion of air-termination elements, conductors and connections;
- corrosion of earth electrodes;
- earthing resistance value for the earth-termination system;
- condition of connections, equipotential bonding and fixings.

7.3 Maintenance

Regular inspections are among the fundamental conditions for reliable maintenance of an LPS. The property owner shall be informed of all observed faults and they shall be repaired without delay.

8 Protection measures against injury to living beings due to touch and step voltages

8.1 Protection measures against touch voltages

In certain conditions, the vicinity of the down-conductors of an LPS, outside the structure, may be hazardous to life even if the LPS has been designed and constructed according to the above-mentioned requirements.

The hazard is reduced to a tolerable level if one of the following conditions is fulfilled:

- a) the probability of persons approaching, or the duration of their presence outside the structure and close to the down-conductors, is very low;
- b) the natural down-conductor system consists of several columns of the extensive metal framework of the structure or of several pillars of interconnected steel of the structure, with the electrical continuity assured;
- c) the resistivity of the surface layer of the soil, within 3 m of the down-conductor, is not less than 5 kΩm.

NOTE A layer of insulating material, e.g. asphalt, of 5 cm thickness (or a layer of gravel 15 cm thick) generally reduces the hazard to a tolerable level.

If none of these conditions are fulfilled, protection measures shall be adopted against injury to living beings due to touch voltages as follows:

- insulation of the exposed down-conductor is provided giving a 100 kV, 1,2/50 μs impulse withstand voltage, e.g. at least 3 mm cross-linked polyethylene;
- physical restrictions and/or warning notices to minimize the probability of down-conductors being touched.

Protection measures shall conform to the relevant standards (see ISO 3864-1).

8.2 Protection measures against step voltages

In certain conditions, the vicinity of the down-conductors outside the structure may be hazardous to life even if the LPS has been designed and constructed according to the above-mentioned rules.

The hazard is reduced to a tolerable level if one of the following conditions is fulfilled:

- a) the probability of persons approaching, or the duration of their presence in the dangerous area within 3 m from the down-conductors, is very low;
- b) the resistivity of the surface layer of the soil, within 3 m of the down-conductor, is not less than 5 kΩm.

NOTE 1 A layer of insulating material, e.g. asphalt, of 5 cm thickness (or a layer of gravel 15 cm thick) generally reduces the hazard to a tolerable level.

If none of these conditions is fulfilled, protection measures shall be adopted against injury to living beings due to step voltages as follows:

- equipotentialization by means of a meshed earthing system;
- physical restrictions and/or warning notices to minimize the probability of access to the dangerous area, within 3 m of the down-conductor.

Protection measures shall conform to the relevant standards (see ISO 3864-1).

Annex A (normative)

Positioning the air-termination system

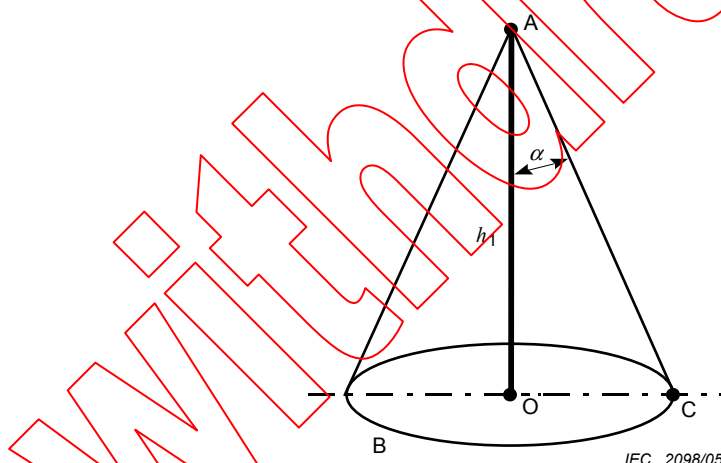
A.1 Positioning the air-termination system when utilizing the protective angle method

The position of the air-termination system is considered to be adequate if the structure to be protected is fully situated within the protected volume provided by the air-termination system.

For the determination of the volume protected only the real physical dimensions of the metal air-termination systems shall be considered.

A.1.1 Volume protected by a vertical rod air-termination system

The volume protected by a vertical rod is assumed to have the shape of a right circular cone with the vertex placed on the air-termination axis, semi-apex angle α , depending on the class of LPS, and on the height of the air-termination system as given in Table 2. Examples of the protected volume are given in Figures A.1 and A.2.



Key

A tip of an air-termination rod

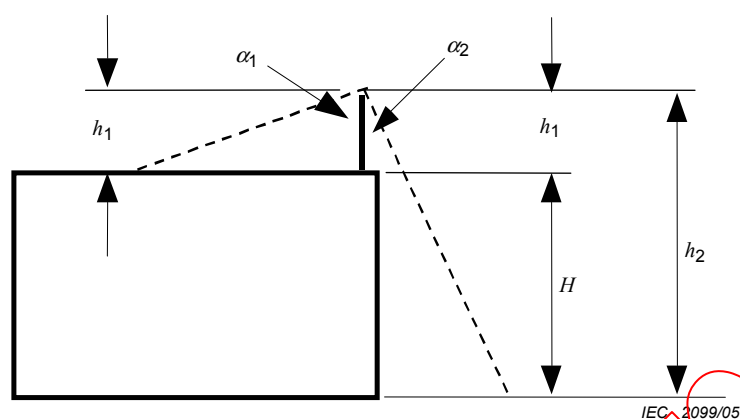
B reference plane

OC radius of protected area

h_1 height of an air-termination rod above the reference plane of the area to be protected

α protective angle according to Table 2

Figure A.1 – Volume protected by a vertical air-termination rod

**Key**

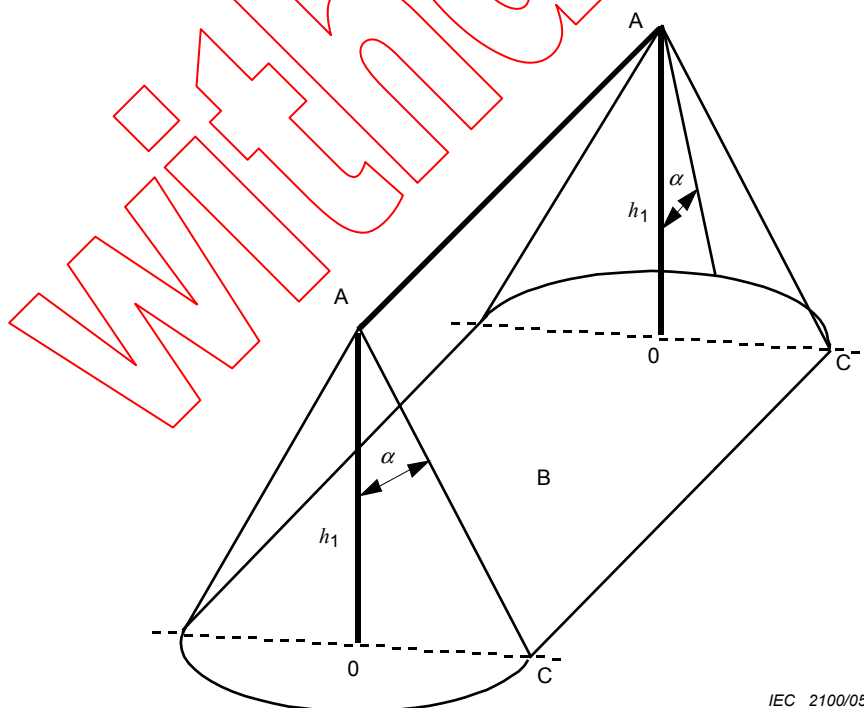
h_1 physical height of an air-termination rod

NOTE The protective angle α_1 corresponds to the air-termination height h_1 , being the height above the roof surface to be protected; the protective angle α_2 corresponds to the height $h_2 = h_1 + H$, the ground being the reference plane; α_1 is related to h_1 and α_2 is related to h_2 .

Figure A.2 – Volume protected by a vertical air-termination rod

A.1.2 Volume protected by a wire air-termination system

The volume protected by a wire is defined by the composition of the volume protected by virtual vertical rods having vertexes on the wire. Examples of the protected volume are given in Figure A.3.



NOTE See Figure A.1 for key.

Figure A.3 – Volume protected by a wire air-termination system

A.1.3 Volume protected by wires combined in a mesh

The volume protected by wires combined in a mesh is defined by a combination of the protected volume determined by the single conductors forming the mesh.

Examples of the volume protected by wires combined in a mesh is given in Figures A.4 and A.5.

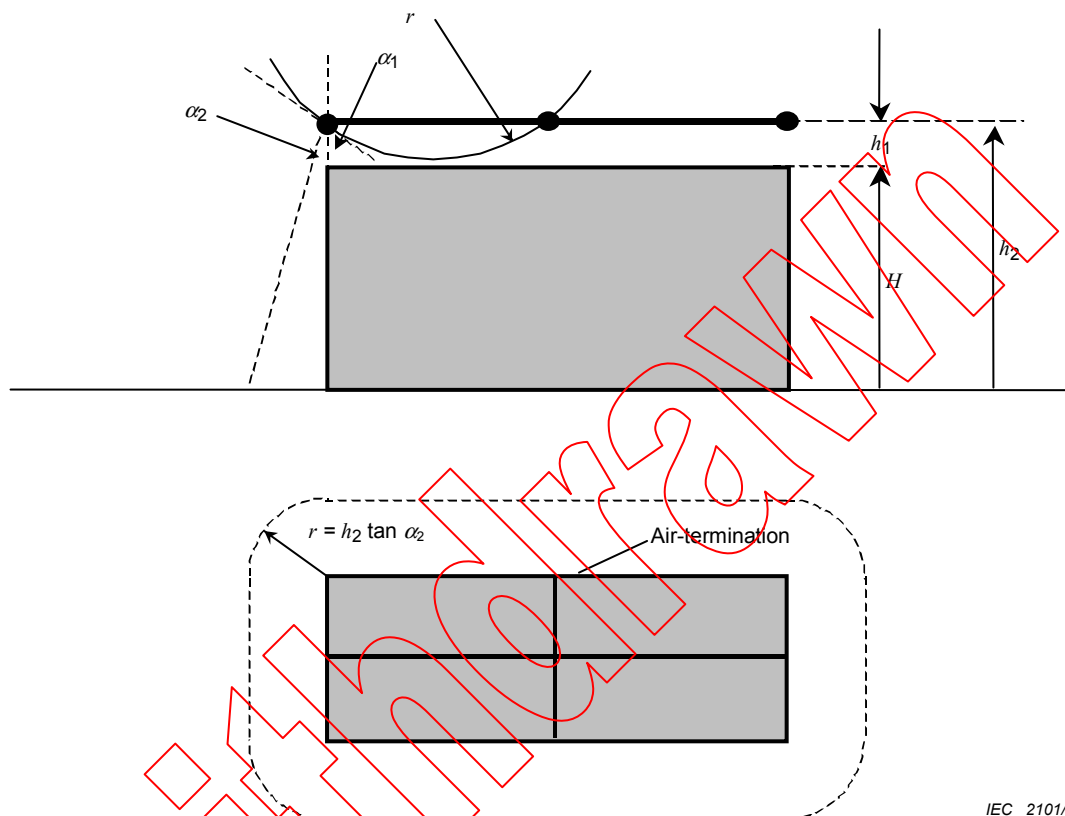
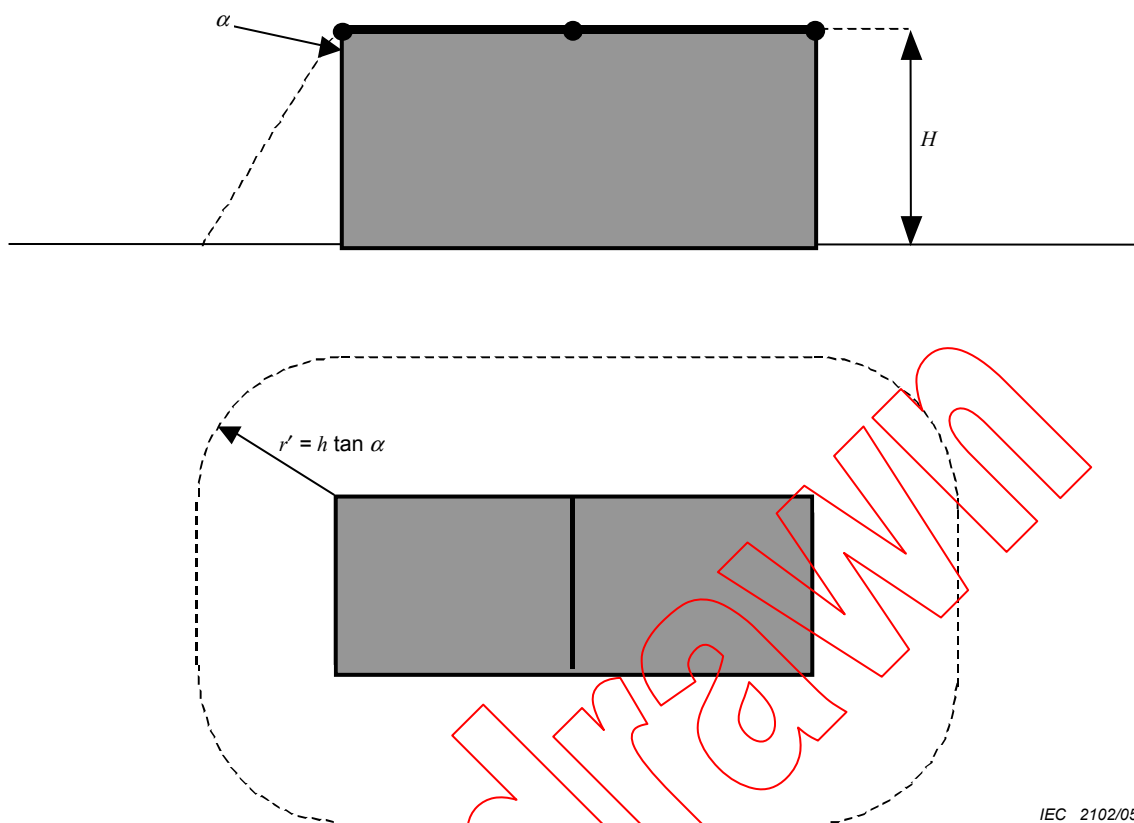


Figure A.4 – Volume protected by isolated wires combined in a mesh according to the protective angle method and rolling sphere method



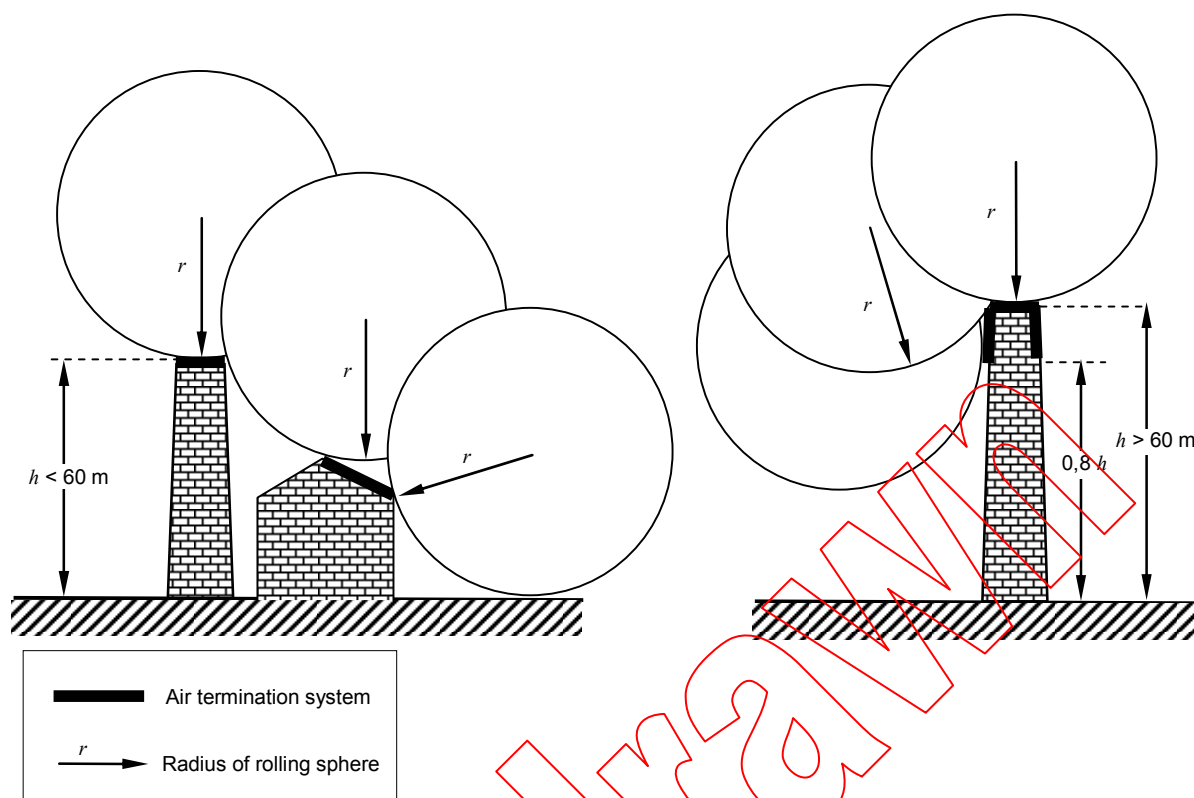
IEC 2102/05

NOTE $H = h$.

Figure A.5 – Volume protected by non-isolated wires combined in a mesh according to the mesh method and the protective angle method

A.2 Positioning of the air-termination system utilizing the rolling sphere method

Applying this method, the positioning of the air-termination system is adequate if no point of the structure to be protected comes into contact with a sphere with radius, r , depending on the class of LPS (see Table 2), rolling around and on top of the structure in all possible directions. In this way, the sphere only touches the air-termination system (see Figure A.6).



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NOTE 1 The rolling sphere radius r should comply with the selected class of LPS (see Table 2).

NOTE 2 $H = h$.

Figure A.6 – Design of an air-termination system according to the rolling sphere method

On all structures higher than the rolling sphere radius r , flashes to the side of structure may occur. Each lateral point of the structure touched by the rolling sphere is a possible point of strike. However, the probability for flashes to the sides is generally negligible for structures lower than 60 m.

For taller structures, the major part of all flashes will hit the top, horizontal leading edges and corners of the structure. Only a few per cent of all flashes will be to the side of the structure.

Moreover, observation data show that the probability of flashes to the sides decreases rapidly as the height of the point of strike on tall structures when measured from the ground. Therefore consideration should be given to install a lateral air-termination system on the upper part of tall structures (typically the top 20 % of the height of the structure). In this case the rolling sphere method will be applied only to the positioning of the air-termination system of the upper part of the structure.

A.3 Positioning of the air-termination system utilizing the mesh method

For the purposes of protecting flat surfaces, a mesh is considered to protect the whole surface, dependent upon all of the following conditions being fulfilled:

- a) Air-termination conductors are positioned
 - on roof edge lines,
 - on roof overhangs,
 - on roof ridge lines, if the slope of the roof exceeds 1/10.

NOTE 1 The mesh method is suitable for horizontal and inclined roofs with no curvature.

NOTE 2 The mesh method is suitable for flat lateral surfaces to protect against side flashes.

NOTE 3 If the slope of the roof exceeds 1/10, parallel air-termination conductors, instead of a mesh, may be used provided the distance between the wires is not greater than the required mesh width.

- b) The mesh dimensions of the air-termination network are not greater than the values given in Table 2.
- c) The network of the air-termination system is constructed in such a way that the lightning current will always encounter at least two distinct metal routes to earth termination.
- d) No metal installation protrudes outside the volume protected by air-termination systems.

NOTE 4 Further information can be found in Annex E.

- e) The air-termination conductors follow, as far as possible, the shortest and most direct route.

Withdrawn

Annex B

(normative)

Minimum cross-section of the entering cable screen in order to avoid dangerous sparking

The overvoltages between the active conductors and the screen of a cable may cause dangerous sparking due to the lightning current carried by the screen. The overvoltages depend on the material, the dimensions of the screen, and the length and positioning of the cable.

The minimum value S_{cmin} (in mm²) of the cross-sectional area of the screen to avoid dangerous sparking is given by:

$$S_{cmin} = \frac{I_f \times \rho_c \times L_c \times 10^6}{U_w} \quad (\text{mm}^2) \quad (\text{B.1})$$

where

I_f is the current flowing on the screen, in kA;

ρ_c is the resistivity of the screen, in Ωm ;

L_c is the cable length, in m (see Table B.1);

U_w is the impulse withstand voltage of the electrical/electronic system fed by the cable, in kV.

Table B.1 – Cable length to be considered according to the condition of the screen

Condition of the screen	L_c
In contact with a soil with resistivity ρ (Ωm)	$L_c \leq 8 \times \sqrt{\rho}$
Insulated from the soil or in air	L_c distance between the structure and the closest earthing point of the screen

NOTE It should be ascertained whether an unacceptable temperature rise for the insulation of the line could occur when the lightning current flows along the line shield or the line conductors. For detailed information, see IEC 62305-4.

The limits of the current are given:

– for shielded cables, by $I_f = 8 \times S_c$; and

– for unshielded cables, by $I_f = 8 \times n' \times S'_c$

where

I_f is the current on the screen, in kA;

n' is the number of conductors;

S_c is the cross-section of the screen, in mm²;

S'_c is the cross-section of each conductor, in mm².

Annex C (informative)

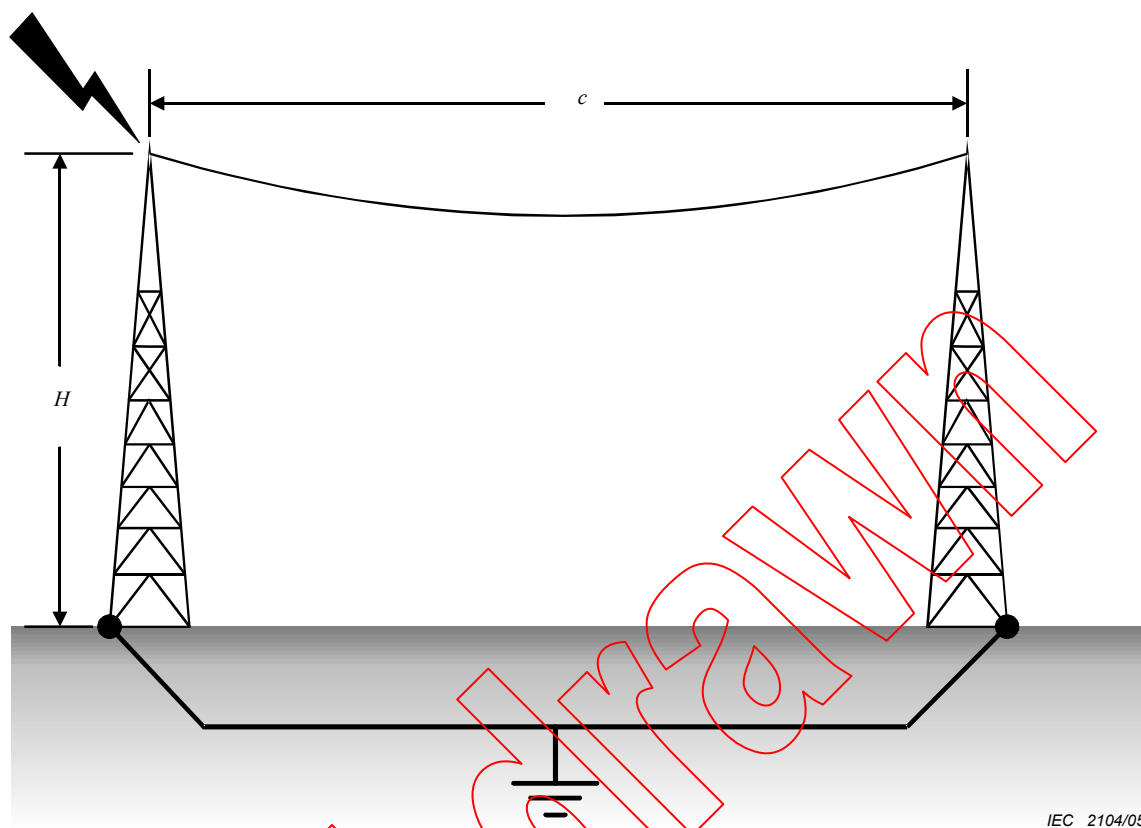
Partitioning of the lightning current amongst down-conductors

The partitioning coefficient k_c of the lightning current amongst the down-conductors depends on the overall number of down-conductors n and their position, the interconnecting ring conductors, the type of air-termination system and the type of earth-termination system as indicated in Table C.1.

Table C.1 applies for type A earthing arrangements, provided that the earthing resistance of each electrode has a similar value, and for all type B earthing arrangements.

Table C.1 – Values of coefficient k_c

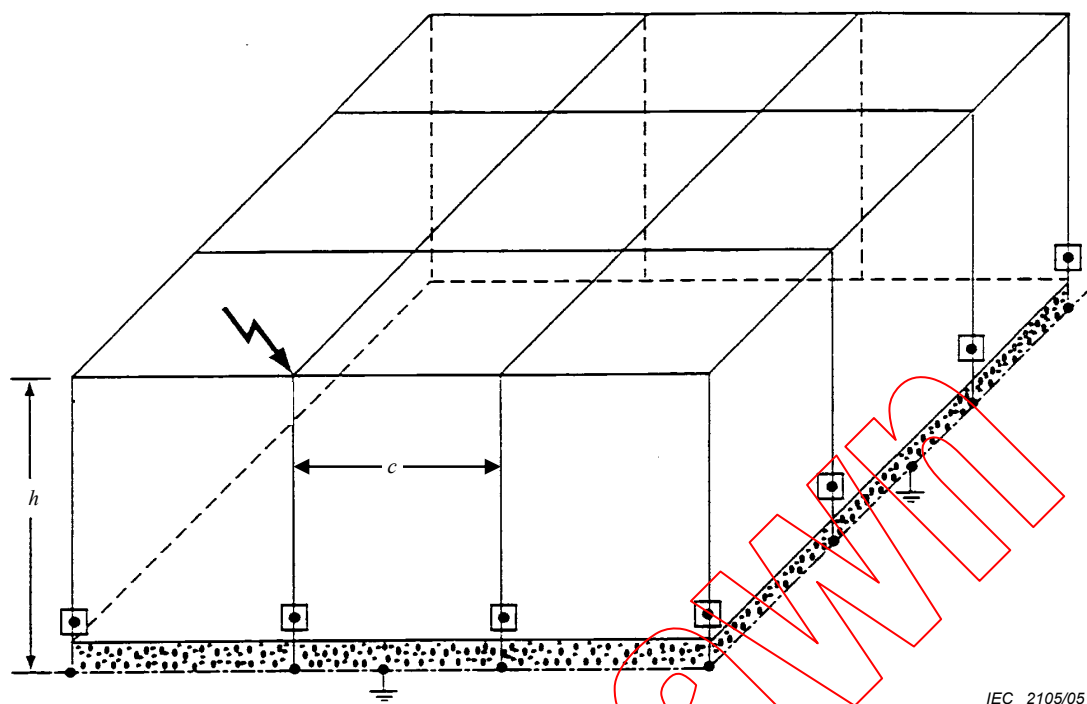
Type of air-termination system	Number of down-conductors n	k_c	
		Earthing arrangement type A	Earthing arrangement type B
Single rod	1	1	1
Wire	2	0,66 ^{d)}	0,5... 1 (see Figure C.1) ^{a)}
Mesh	4 and more	0,44 ^{d)}	0,25... 0,5 (see Figure C.2) ^{b)}
Mesh	4 and more, connected by horizontal ring conductors	0,44 ^{d)}	1/ n ... 0,5 (see Figure C.3) ^{c)}
a) Values range from $k_c = 0,5$ where $c \ll h$ to $k_c = 1$ with $h \ll c$ (see Figure C.1). b) The equation for k_c according to Figure C.2 is an approximation for cubic structures and for $n \geq 4$. The values of h, c_s and c_d are assumed to be in the range of 5 m to 20 m. c) If the down-conductors are connected horizontally by ring conductors, the current distribution is more homogeneous in the lower parts of the down-conductor system and k_c is further reduced. This is especially valid for tall structures. d) These values are valid for single earthing electrodes with comparable earthing resistances. If earthing resistances of single earthing electrodes are clearly different, $k_c = 1$ is to be assumed			
NOTE Other values of k_c may be used if detailed calculations are performed.			



$$k_c = \frac{h+c}{2h+c}$$

NOTE $H = h$.

Figure C.1 – Values of coefficient k_c in the case of a wire air-termination system and a type B earth-termination system



$$k_c = \frac{1}{2n} + 0,1 + 0,2 \times \sqrt[3]{\frac{c}{h}}$$

Key

- n total number of down-conductors
 c distance of a down-conductor to the next down-conductor
 h spacing (or height) between ring conductors

NOTE 1 For a detailed evaluation of coefficient k_c values, see Figure C.3.

NOTE 2 If internal down-conductors exist, they should be taken into account in evaluating k_c .

Figure C.2 – Values of coefficient k_c in the case of a mesh air-termination system and type B earth-termination system

$$d_a \geq s_a = \frac{k_i}{k_m} \times k_{c1} \times l_a \quad d_b \geq s_b = \frac{k_i}{k_m} \times k_{c2} \times l_b$$

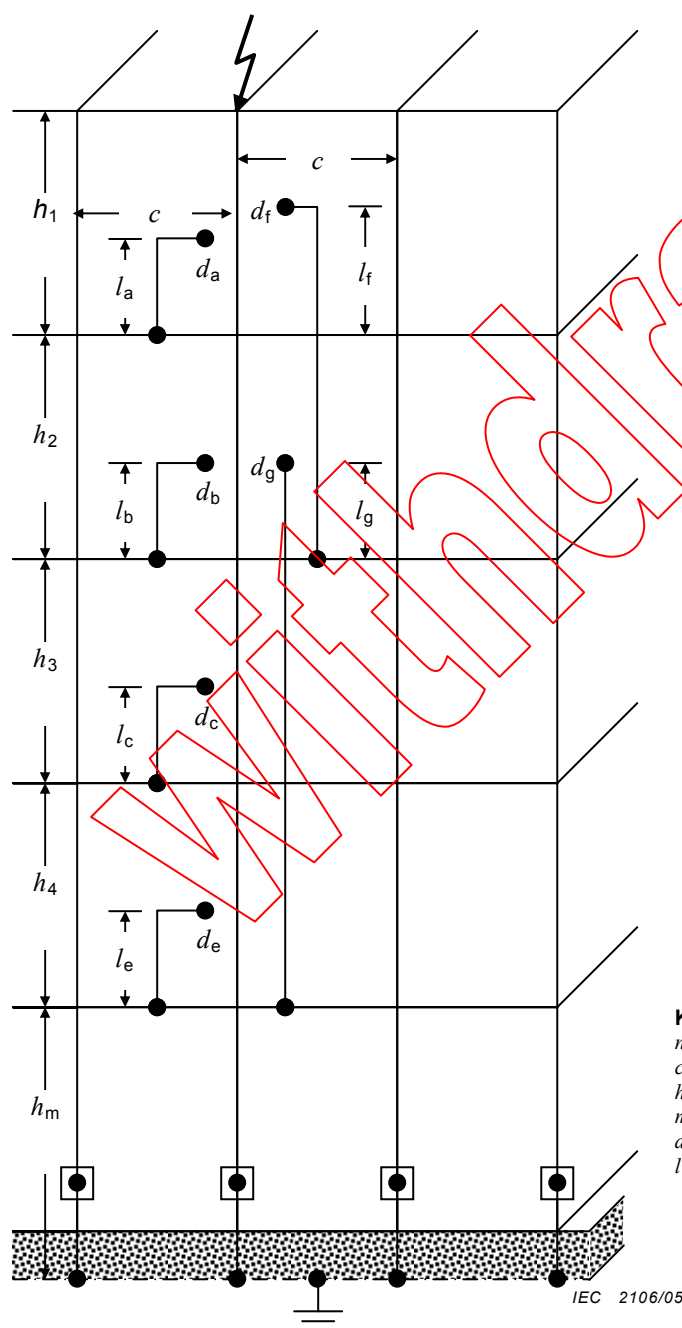
$$d_c \geq s_c = \frac{k_i}{k_m} \times k_{c3} \times l_c$$

$$d_e \geq s_e = \frac{k_i}{k_m} \times k_{c4} \times l_e \quad d_f \geq s_f = \frac{k_i}{k_m} \times (k_{c1} \times l_f + k_{c2} \times h_2) \quad d_g \geq s_g = \frac{k_i}{k_m} \times (k_{c2} \times l_g + k_{c3} \times h_3 + k_{c4} \times h_4)$$

$$d_a \geq s_a = \frac{k_i}{k_m} \times k_{c1} \times l_a \quad d_b \geq s_b = \frac{k_i}{k_m} \times k_{c2} \times l_b$$

$$d_c \geq s_c = \frac{k_i}{k_m} \times k_{c3} \times l_c$$

$$d_e \geq s_e = \frac{k_i}{k_m} \times k_{c4} \times l_e \quad d_f \geq s_f = \frac{k_i}{k_m} \times (k_{c1} \times l_f + k_{c2} \times h_2) \quad d_g \geq s_g = \frac{k_i}{k_m} \times (k_{c2} \times l_g + k_{c3} \times h_3 + k_{c4} \times h_4)$$



$$k_c = \frac{1}{2n} + 0,1 + 0,2 \times \sqrt{\frac{c}{h}}$$

$$k_{c2} = \frac{1}{n} + 0,1$$

$$k_{c3} = \frac{1}{n} + 0,01$$

$$k_{c4} = \frac{1}{n}$$

$$k_{cm} = k_{c4} = \frac{1}{n}$$

Key

- n Total number of down-conductors
- c Distance from the nearest down-conductor
- h Spacing (height) between ring conductors
- m Total number of levels
- d Distance to the nearest down-conductor
- l Height above the bonding point

Figure C.3 – Examples of calculation of the separation distance in the case of a meshed air-termination system, an interconnecting ring of the down-conductors at each level and a type B earth-termination system

Annex D (informative)

Additional information for LPS in the case of structures with a risk of explosion

D.1 General

This annex supplies additional information for the design, construction, extension and modification of lightning protection systems for structures with a risk of explosion.

NOTE 1 Information provided in this annex is based on practically proven configurations of lightning protection systems installed in applications where a danger of explosion exists.

Where protection against lightning is required by the authority having jurisdiction, or as result of risk assessment performed in accordance with IEC 62305-2, at least a class II LPS should be adopted. Supplemental information is provided in this annex for specific applications.

NOTE 2 Exceptions to the use of lightning protection level II may be allowed when technically justified and authorized by the authority having jurisdiction. For example, the use of lightning protection level I is allowed in all cases, especially in those cases where the environments or contents within the structure are exceptionally sensitive to the effects of lightning. In addition, authorities having jurisdiction may choose to allow lightning protection level III systems where the infrequency of lightning activity and/or the insensitivity of the contents of the structure warrants such.

D.2 Additional terms and definitions

In addition to the terms and definitions of Clause 3 of this standard, the following terms and definitions are applicable to this annex.

D.2.1

isolating spark gap

component with discharge distance for isolating electrically-conductive installation sections

NOTE In the event of a lightning flash, the installation sections are temporarily connected conductively as the result of the discharge.

D.2.2

solid explosives material

solid chemical compound, mixture, or device with explosion as its primary or common purpose

D.2.3

zone 0

place in which an explosive atmosphere consisting of a mixture of air and flammable substances in the form of gas, vapour or mist is present continuously or for long periods or frequently

[IEV 426-03-03, modified]

D.2.4

zone 1

place in which an explosive atmosphere consisting of a mixture of air and flammable substances in the form of gas, vapour or mist is likely to occur in normal operation occasionally

[IEV 426-03-04, modified]