IEC 62305-3

Edition 2.0 2010-12

INTERNATIONAL STANDARD

NORME INTERNATIONALE

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

Protection contre la foudre – Partie 3: Dommages physiques sur les structures et risques humains

IEC 62305-3:2010

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

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

ICS 29.020; 91.120.40

ISBN 978-2-83220-129-9

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PROTECTION AGAINST LIGHTNING –

Part 3: Physical damage to structures and life hazard

FOREWORD

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International Standard IEC 62305-3 has been prepared by IEC technical committee 81: Lightning protection.

This second edition cancels and replaces the first edition, published in 2006, and constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

1) Minimum thicknesses of metal sheets or metal pipes given in Table 3 for air-termination systems are assumed as not able to prevent hot-spot problems.
2) Steel with electro-deposited copper is introduced as material suitable for LPS.
3) Some cross-sectional areas of LPS conductors were slightly modified.
4) For bonding purposes, isolating spark gaps are used for metal installations and SPD for internal systems.

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5) Two methods – simplified and detailed – are provided for evaluation of separation distance.
6) Protection measures against injuries of living beings due to electric shock are considered also inside the structure.
7) Improved information for LPS in the case of structures with a risk of explosion are given in Annex D (normative).

This bilingual version (2012-06) corresponds to the monolingual English version, published in 2010-12.

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

FDIS	Report on voting
81/372/FDIS	81/382/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.

The French version of this standard has not been voted upon.

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

A list of all the parts in the IEC 62305 series, under the general title *Protection against lightning*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "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:2008 [1] [1] 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 and Portugal:

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

In Russia the use of piping carrying and tanks containing readily-combustible or explosive materials as air-termination natural components or down-conductor natural components are not allowed in any case.

In Japan the minimum values of the cross-section are reduced from:

– 16 mm^2 to 14 mm^2 for copper and 25 mm^2 to 22 mm^2 for aluminium, for bonding conductors connecting different bonding bars and conductors connecting the bars to the earth-termination system;
– 6 mm^2 to 5 mm^2 for copper, 10 mm^2 to 8 mm^2 for aluminium and 16 mm^2 to 14 mm^2 for steel, for bonding conductors connecting internal metal installations to the bonding bars.

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1 References in square brackets refer to the bibliography.

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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.

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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.

NOTE 3 Specific requirements for protection against lightning of wind turbines are reported in IEC 61400-24 [2].

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 60079-10-1:2008, *Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres*

IEC 60079-10-2:2009, *Explosive atmospheres – Part 10-2: Classification of areas – Combustible dust atmospheres*

IEC 60079-14:2007, *Explosive atmospheres – Part 14: Electrical installations design, selection and erection*

IEC 61557-4, *Electrical safety in low-voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. – Equipment for testing, measuring or monitoring of protective measures – Part 4: Resistance of earth connection and equipotential bonding*

IEC 61643-1, *Low-voltage surge protective devices – Part 1: Surge protective devices connected to low-voltage power distribution systems – Requirements and tests*

IEC 61643-21, *Low-voltage surge protective devices – Part 21: Surge protective devices connected to telecommunications and signalling networks – Performance requirements and testing methods*

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

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

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

IEC 62561 (all parts)[2], *Lightning protection system components (LPSC)*

IEC 62561-1[2], *Lightning protection system components (LPSC) – Part 1: Requirements for connection components*

IEC 62561-3[2], *Lightning protection system components (LPSC) – Part 3: Requirements for isolating spark gaps*

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

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3.7
down-conductor system
part of an external LPS intended to conduct lightning current between the air-termination system and the earth-termination system

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

3.11
ring earth electrode
earth electrode forming a closed loop around the structure below or on the surface of the earth

3.12
foundation earth electrode
conductive part buried in the soil under a building foundation or, preferably, embedded in concrete of a building foundation, generally in form of a closed loop

[IEC 60050-826:2004, 826-13-08] [3]

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 earth electrode.

3.16
connecting component
part of an LPS which is used for the connection of conductors to each other or to metallic installations

NOTE This also includes bridging component and expansion piece.

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3.17
fixing component
part of an 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, interconnected reinforcing steel, structural metal parts

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

3.21
electronic system
system incorporating sensitive electronic components such as telecommunication 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 tele-communication 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

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3.29
surge protective device
SPD
device intended to limit transient overvoltages and divert surge currents; 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 60079-10-1 and IEC 60079-10-2

3.35
isolating spark gap
ISG
component with discharge distance for isolating electrically conductive installation sections

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

3.36
isolating interfaces
devices which are capable of reducing conducted surges on lines entering the LPZ

NOTE 1 These include isolation transformers with earthed screen between windings, metal-free fibre optic cables and opto-isolators.

NOTE 2 Insulation withstand characteristics of these devices are suitable for this application intrinsically or via SPD.

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), as shown in Table 1, are defined in this standard corresponding to lightning protection levels defined in IEC 62305-1.

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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 62305-1:2010);
   – rolling sphere radius, mesh size and protection angle (see 5.2.2);
   – typical preferred distances between down-conductors (see 5.3.3);
   – separation distance against dangerous sparking (see 6.3);
   – minimum length of earth electrodes (see 5.4.2).

b) Factors 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 5.5.1);
   – 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 62305-2:2010.

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.

The LPS should be designed and installed by well-trained and expert LPS designers and installers (see E.4.2)

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 (see Figure E.5). For new structures, the connections between reinforcement

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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 system 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.

NOTE 3 Clamps to establish the continuity of steelwork in reinforced concrete should comply with IEC 62561-1.

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, or 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 steel-reinforcement, metal framework of the structure, etc.) may be used as parts of an LPS.

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

NOTE For further information, see Annex E.

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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. All types of air terminals shall comply in full with this standard.

For all types of air terminals only the real physical dimensions of the metal air-termination systems shall be used for the determination of the volume protected.

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 and Figure 1. Detailed information on the positioning of the air-termination system is given in Annex A.

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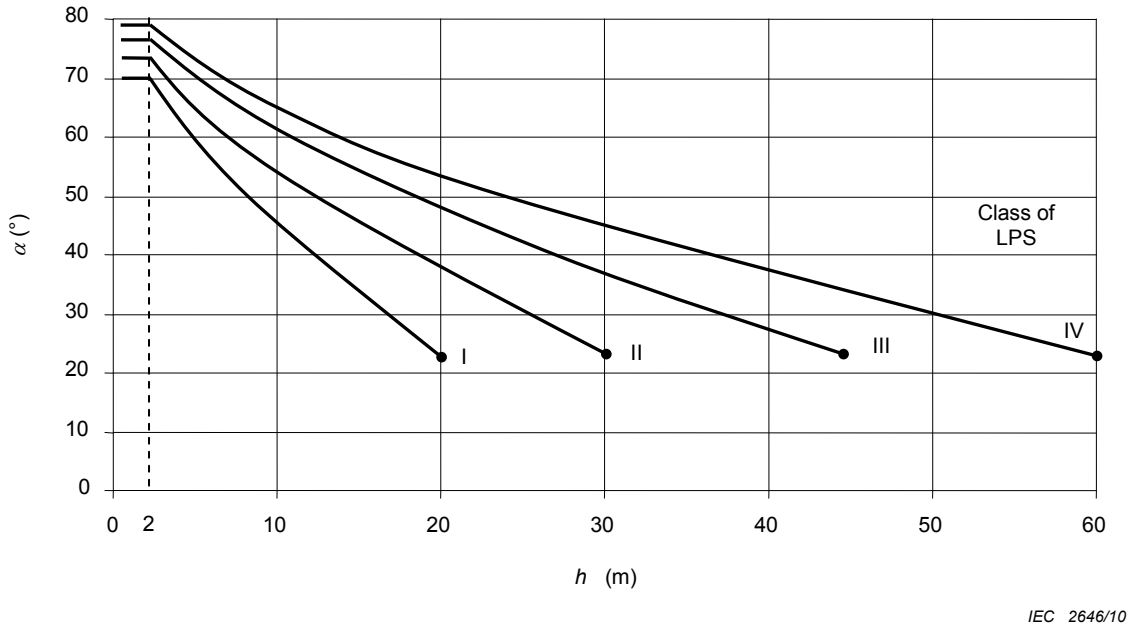
Table 2 – Maximum values of rolling sphere radius, mesh size and protection angle corresponding to the class of LPS

	Protection method		
Class of LPS	**Rolling sphere radius *r*** m	**Mesh size w_m** m	**Protection angle** $\alpha°$
I	20	5 × 5	See Figure 1 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.

Figure 1 – Protection angle corresponding to the class of LPS

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

5.2.3.1 Structures less than 60 m tall

Research indicates that the probability of low amplitude strikes to the vertical side of a structure of less than 60 m in height are low enough that they need not be considered. Roofs and horizontal protrusions shall be protected in accordance with the class of LPS determined by the risk calculations of IEC 62305-2.

5.2.3.2 Structures 60 m in height or more

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

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NOTE 1 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 as far as this part exceeds 60 m in height) and the equipment installed on it (see Annex A).

The rules for positioning the air-termination systems on these upper parts of a structure shall meet at least the requirements for LPL IV with emphasis on the location of air-termination devices on corners, edges, and significant protrusions (such as balconies, viewing platforms, etc.).

The air-termination requirement for the side of a tall structure may be satisfied by the presence of external metallic materials such as metal cladding or metallic curtain walls provided they meet the minimum size requirements of Table 3. The air-termination requirement may also include the use of external down-conductors located on the vertical edges of the structure when not provided by natural external metallic conductors.

The installed or naturally occurring air-terminations meeting these requirements may utilize installed down-conductors or be suitably interconnected with natural down-conductors such as the steel frame of the structure or the metal of electrically-continuous reinforced concrete meeting the requirements of 5.3.5.

NOTE 2 Use of suitable earth-termination and natural down-conductors is encouraged.

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 mounting of the reed, a distance of at least 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 highest probable water level.

5.2.5 Natural components

The following parts of a structure should be considered and may be used 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,

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– 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,

NOTE 1 Where hot spot or ignition problems may arise, it should be verified that the temperature rise of the inner surface at the point of strike does not constitute a danger. Hot spot or ignition problems can be disregarded when the metal sheets lies inside an $LPZ0_B$ or higher.

– 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.

[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 damage to this non-metallic roofing is acceptable.

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 D).

If the conditions for thickness are not fulfilled, the pipes and tanks shall be included 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 2 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 E.5.3.4.1 and in E.5.3.4.2.

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;

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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 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 preferred distance between down-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

The positioning shall be as follows:

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 preferred 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 preferred values of the distance between down-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.

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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 2) shall conform to 6.3.

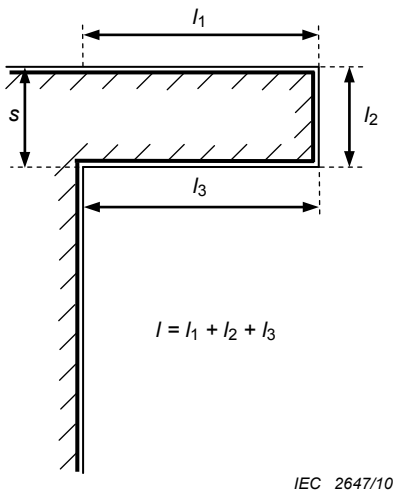

Figure 2 – Loop in a down-conductor

Down-conductors, even if covered in insulating material, shall not be installed in gutters or water spouts.

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 steel or thermal equivalent conductor shall be not less than 100 mm^2.

5.3.5 Natural components

The following parts of the structure may be used as natural down-conductors:

a) the metal installations provided that

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– the electrical continuity between the various parts is made durable in accordance with 5.5.3,

– 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 5.5.3.

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.

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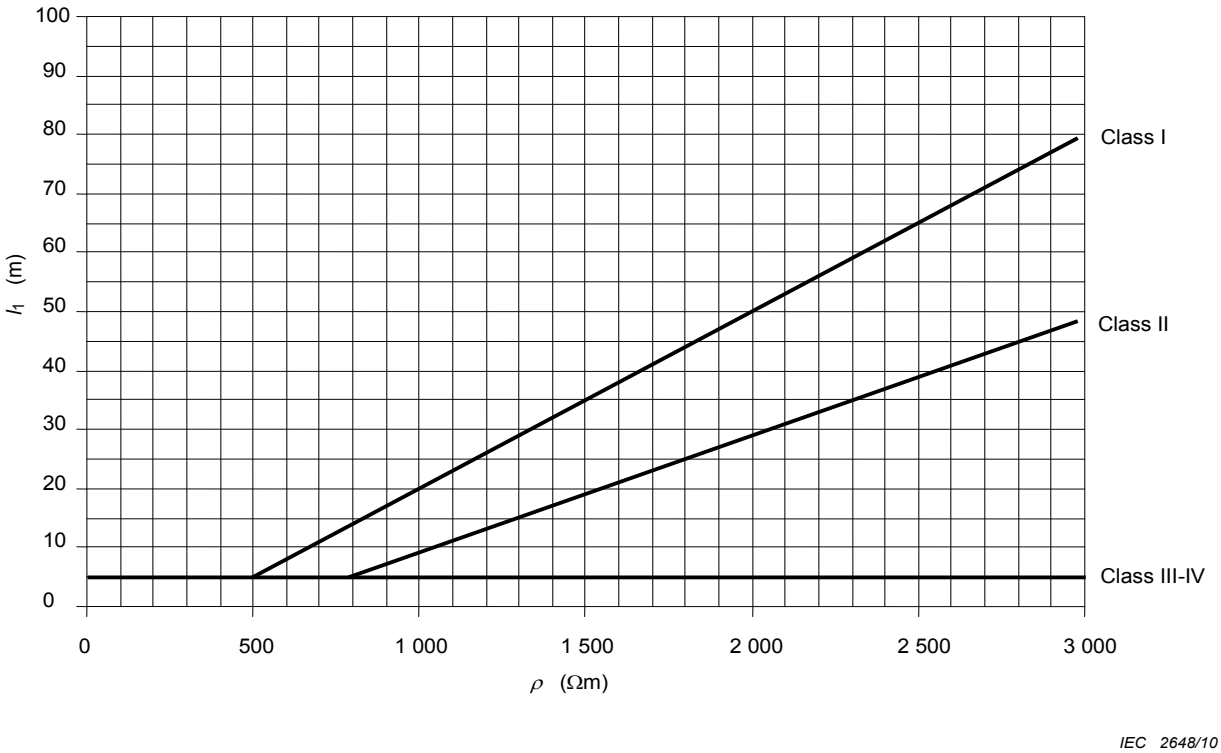
5.4.2 Earthing arrangement in general conditions

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 or foundation earth electrodes not forming a closed loop.

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 3 – 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 3.

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

The minimum lengths stated in Figure 3 may be disregarded provided that an earthing resistance of the earth-termination system less than 10 Ω (measured at a frequency different from the power frequency and its multiple in order to avoid interference) is achieved.

NOTE 1 When the above-mentioned requirements cannot be met, a type B earth arrangement shall be used.

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NOTE 2 Reduction of earthing resistance by the extension of earth electrodes is practically convenient up to 60 m. In soil with resistivity higher than 3 000 Ωm, the use of type B earth electrodes or earthing enhancing compounds is recommended.

NOTE 3 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 forming a closed loop. Such earth electrodes may also be meshed.

NOTE Although 20 % may not be in contact with the soil, the ring conductor must always be completely connected throughout its total length.

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 3 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 away from 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.

NOTE 1 If the type A earth electrode is positioned within an inspection housing which, in turn, is located in high resistance paving or adjoining concrete, then the 0,5 m requirement can be disregarded.

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 2 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, a type B earthing arrangement is recommended.

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For structures with extensive electronic systems or with high risk of fire, 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

5.5.1 General

Components of LPS shall withstand the electromagnetic effects of lightning current and predictable accidental stresses without being damaged. This can be achieved by choosing components that have successfully been tested in accordance with the future IEC 62561 series.

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 [a]

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[c, d, e]	Solid Stranded [b]	Solid	Solid Stranded [b]	Acceptable in air, in concrete and in benign soil	High chlorides content	Copper
Steel with electro-deposited copper	Solid	Solid	Solid	Good in many environments	Sulphur compounds	
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

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Lead [f]	Solid As coating	Solid As coating	Unsuitable	Good in atmosphere with high concentration of sulphates	Acid soils	Copper Stainless steel

[a] This table gives general guidance only. In special circumstances, more careful corrosion immunity considerations are required (see Annex E).

[b] 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.

[c] Galvanized steel may be corroded in clay soil or moist soil.

[d] Galvanized steel in concrete should not extend into the soil due to possible corrosion of the steel just outside the concrete.

[e] Galvanized steel in contact with reinforcement steel in concrete should not be used in coastal areas where there may be salt in the ground water.

[f] Use of lead in the earth is often banned or restricted due to environmental concerns.

5.5.2 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 62305-1:2010).

NOTE Recommended distances between fixings are reported in Table E.1.

5.5.3 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.

To achieve this, connections of steelwork within reinforced concrete structures shall conform to 4.3 and shall comply with the requirements and tests according to IEC 62561-1.

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 and shall comply with the requirements and tests according to the future IEC 62561 series.

Configurations and minimum dimensions of earth electrodes are given in Table 7 and shall comply with the requirements and tests according to the future IEC 62561 series.

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Table 6 – Material, configuration and minimum cross-sectional area of air-termination conductors, air-termination rods, earth lead-in rods and down-conductors [a]

Material	Configuration	Cross-sectional area mm^2
Copper, Tin plated copper	Solid tape	50
	Solid round [b]	50
	Stranded [b]	50
	Solid round [c]	176
Aluminium	Solid tape	70
	Solid round	50
	Stranded	50
Aluminium alloy	Solid tape	50
	Solid round	50
	Stranded	50
	Solid round [c]	176
Copper coated aluminium alloy	Solid round	50
Hot dipped galvanized steel	Solid tape	50
	Solid round	50
	Stranded	50
	Solid round[c]	176
Copper coated steel	Solid round	50
	Solid tape	50
Stainless steel	Solid tape [d]	50
	Solid round [d]	50
	Stranded	70
	Solid round [c]	176

[a] Mechanical and electrical characteristics as well as corrosion resistance properties shall meet the requirements of the future IEC 62561 series.

[b] 50 mm^2 (8 mm diameter) may be reduced to 25 mm^2 in certain applications where mechanical strength is not an essential requirement. Consideration should in this case, be given to reducing the spacing between the fasteners.

[c] Applicable for air-termination rods and earth lead-in rods. For air-termination rods where mechanical stress such as wind loading is not critical, a 9,5 mm diameter, 1 m long rod may be used.

[d] If thermal and mechanical considerations are important then these values should be increased to 75 mm^2.

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Table 7 – Material, configuration and minimum dimensions of earth electrodes [a, e]

Material	Configuration	Dimensions		
		Earth rod diameter mm	Earth conductor mm^2	Earth plate mm
Copper Tin plated copper	Stranded		50	
	Solid round	15	50	
	Solid tape		50	
	Pipe	20		
	Solid plate			500 × 500
	Lattice plate [c]			600 × 600
Hot dipped galvanized steel	Solid round	14	78	
	Pipe	25		
	Solid tape		90	
	Solid plate			500 × 500
	Lattice plate [c]			600 × 600
	Profile	[d]		
Bare steel[b]	Stranded		70	
	Solid round		78	
	Solid tape		75	
Copper coated steel	Solid round	14 [f]	50	
	Solid tape		90	
Stainless steel	Solid round	15 [f]	78	
	Solid tape		100	

[a] Mechanical and electrical characteristics as well as corrosion resistance properties shall meet the requirements of the future IEC 62561 series.

[b] Shall be embedded in concrete for a minimum depth of 50 mm.

[c] Lattice plate constructed with a minimum total length of the conductor of 4,8 m.

[d] Different profiles are permitted with a cross-section of 290 mm^2 and a minimum thickness of 3 mm, e.g. cross profile.

[e] In case of a type B arrangement foundation earthing system, the earth electrode shall be correctly connected at least every 5 m with the reinforcement steel.

[f] In some countries the diameter may be reduced to 12,7 mm.

6 Internal lightning protection system

6.1 General

The internal LPS shall prevent 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:

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

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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 D).

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

– 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 are not feasible,
– isolating spark gaps (ISGs), where direct connections with bonding conductors are not allowed.

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, gas pipes 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 1 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.

NOTE 2 Lightning equipotential bonding should be integrated and coordinated with other equipotential bonding in the structure.

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), a ring bonding bar may be used or 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.

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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	16
	Aluminium	25
	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	6
	Aluminium	10
	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 ISGs designed for such an operation.

ISGs shall be tested according to IEC 62561-3 and shall have the following characteristics:

– $I_{imp} \geq k_c I$ where $k_c I$ is the lightning current flowing along the relevant part of the external LPS (see Annex C);
– rated impulse sparkover voltage U_{RIMP} lower than the impulse withstand level of insulation between parts.

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 62305-1:2010.

If direct bonding is not acceptable, ISGs with the following characteristics shall be used.

ISGs shall be tested according to IEC 62561-3 and shall have the following characteristics:

– $I_{imp} \geq I_F$ where I_F is the lightning current flowing along the considered external conductive part (see Annex E of IEC 62305-1:2010);
– the rated impulse sparkover voltage U_{RIMP} lower than the impulse withstand level of insulation between parts.

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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 cables of internal systems 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 cables. For protection of such equipment refer to IEC 62305-4.

If cables 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 an SPD.

Bonding conductors shall have the same current withstand as indicated in 6.2.2 for ISGs.

SPDs shall comply with IEC 61643-1 and IEC 61643-21 and shall have the following characteristics:

– tested with $I_{imp} \geq k_c I$ where $k_c I$ is the lightning current flowing along the relevant part of the external LPS (see Annex C);
– the protection level U_P lower than the impulse withstand level of insulation between parts.

If protection of internal systems against surges is required, a coordinated SPD system conforming to the requirements of Clause 7 of IEC 62305-4:2010 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 an 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 shall have the same current withstand as indicated in 6.2.3 for ISGs.

SPDs shall comply with IEC 61643-1 and IEC 61643-21 and shall have the following characteristics:

– tested with $I_{imp} \geq I_F$ where I_F is the lightning current flowing along the lines (see Annex E of IEC 62305-1:2010);
– the protection level U_P lower than the impulse withstand level of insulation between parts.

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If protection against surges of internal systems connected to lines entering the structure is required, a coordinated SPD system conforming to the requirements of Clause 7 of IEC 62305-4:2010 shall be used.

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.

6.3 Electrical insulation of the external LPS

6.3.1 General

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 separation distance, *s*, between the parts. The general equation for the calculation of *s* is given by:

$$s = \frac{k_i}{k_m} \times k_c \times l \quad \text{(m)} \tag{4}$$

where

k_i depends on the selected class of LPS (see Table 10);

k_m depends on the electrical insulation material (see Table 11);

k_c depends on the (partial) lightning current flowing on the air-termination and the down-conductor(see Table 12 and Annex C);

l is the length, in metres, along the air-termination and the down-conductor from the point where the separation distance is to be considered, to the nearest equipotential bonding point or the earth termination (see E.6.3 of Annex E).

NOTE The length *l* along the air-termination can be disregarded in structures with continuous metal roof acting as natural air-termination system.

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_m

Material	k_m
Air	1
Concrete, bricks, wood	0,5
NOTE 1 When there are several insulating materials in series, it is a good practice to use the lower value for k_m. NOTE 2 In using other insulating materials, construction guidance and the value of k_m should be provided by the manufacturer.	

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

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

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The coefficient k_c of the lightning current amongst the air-terminations/down-conductors depends on the class of LPS, on the overall number *n,* on the position of the down-conductors, on the interconnecting ring conductors and on the type of earth-termination system. The necessary separation distance depends on the voltage drop of the shortest path from the point where the separation distance is to be considered, to the ground electrode or the nearest equipotential bonding point.

6.3.2 Simplified approach

In typical structures for the application of Equation (4), the following conditions have to be considered:

k_c depends on the (partial) lightning current flowing on the down-conductor arrangement (see Table 12 and Annex C);

l is the vertical length, in metres, along the down-conductor, from the point where the separation distance is to be considered, to the nearest equipotential bonding point.

Table 12 – Isolation of external LPS – Approximated values of coefficient k_c

Number of down-conductors *n*	k_c
1 (only in case of an isolated LPS)	1
2	0,66
3 and more	0,44
NOTE Values of Table 12 apply for all type B earthing arrangements and for type A earthing arrangements, provided that the earth resistance of neighbouring earth electrodes do not differ by more than a factor of 2. If the earth resistances of single earth electrodes differ by more than a factor of 2, k_c = 1 is to be assumed.	

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

NOTE The simplified approach usually leads to results being on the safe side.

6.3.3 Detailed approach

In an LPS with a meshed air-termination system or interconnected ring conductors, the air-terminations or down-conductors have different values of current flowing down their lengths due to current division. In these cases a more accurate evaluation of the separation distance, *s,* may be performed by the following relationship:

$$s = \frac{k_i}{k_m} \times (k_{c1} \times l_1 + k_{c2} \times l_2 + \ldots + k_{cn} \times l_n) \quad (5)$$

When the air-terminations or down-conductors have different values of current flowing down their lengths due to interconnecting ring conductors, Figures C.4 and C.5 apply.

NOTE 1 This approach is suitable for evaluation of the separation distance in very large structures or in structures with complex shape.

NOTE 2 For the calculation of the coefficients, k_c on the individual conductors, numerical network programs may be used.

7 Maintenance and inspection of an LPS

7.1 General

The effectiveness of any LPS depends on its installation, maintenance, and testing methods used.

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Inspections, testing and maintenance shall not be conducted during threat of thunderstorms.

NOTE Detailed information on the inspection and maintenance of LPS are provided in Clause E.7.

7.2 Application of inspections

The objective of the inspections is to ascertain that

a) the LPS conforms to the design based on this standard,

b) all components of the LPS are in good condition and capable of performing their designed functions, and that there is no corrosion,

c) any recently added services or constructions are incorporated into the LPS.

7.3 Order of inspections

Inspections should be made according to 7.2 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.

7.4 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, 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) under normal operation conditions there are no persons within 3 m from the down-conductors;

b) a system of at least 10 down-conductors complying with 5.3.5 is employed;

c) the contact resistance of the surface layer of the soil, within 3 m of the down-conductor, is not less than 100 kΩ.

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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 is 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 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) under normal operation conditions there are no persons within 3 m from the down-conductors;
b) a system of at least 10 down-conductors complying with 5.3.5 is employed;
c) the contact resistance of the surface layer of the soil, within 3 m of the down-conductor, is not less than 100 kΩ.

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 is fulfilled, protection measures shall be adopted against injury to living beings due to step voltages as follows:

– equipotentialization by means of a meshed earth-termination 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).

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Annex A
(normative)

Positioning the air-termination system

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

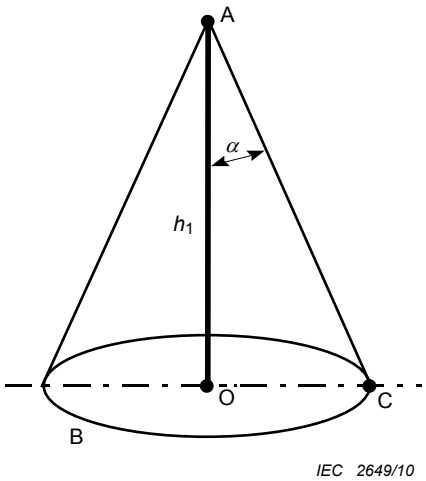
A.1.1 General

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.1.2 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	protection angle according to Table 2

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

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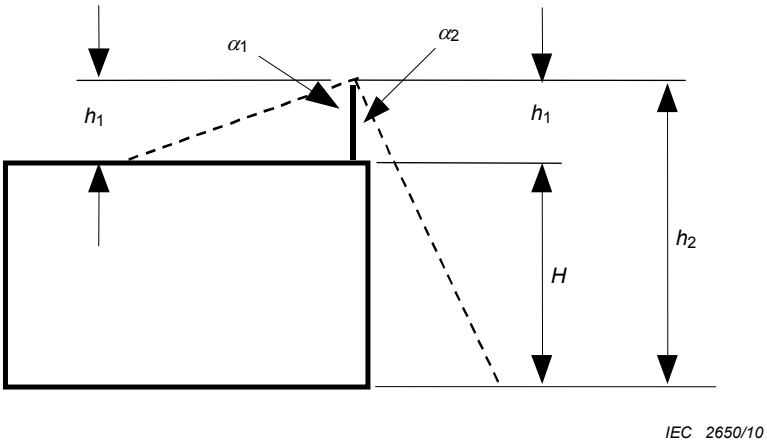


Key

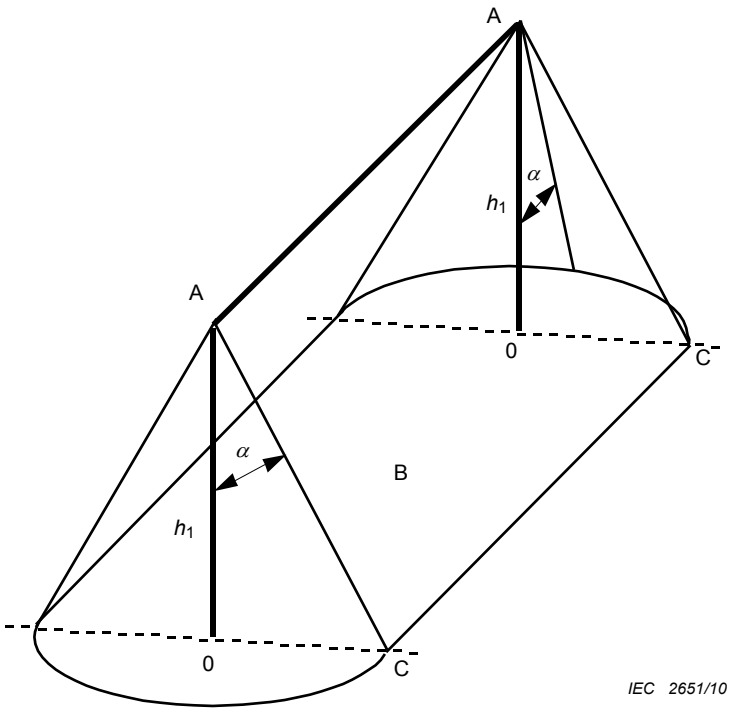
h_1 physical height of an air-termination rod

NOTE The protection angle α_1 corresponds to the air-termination height h_1, being the height above the roof surface to be protected; the protection 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.1.3 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

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A.1.4 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.

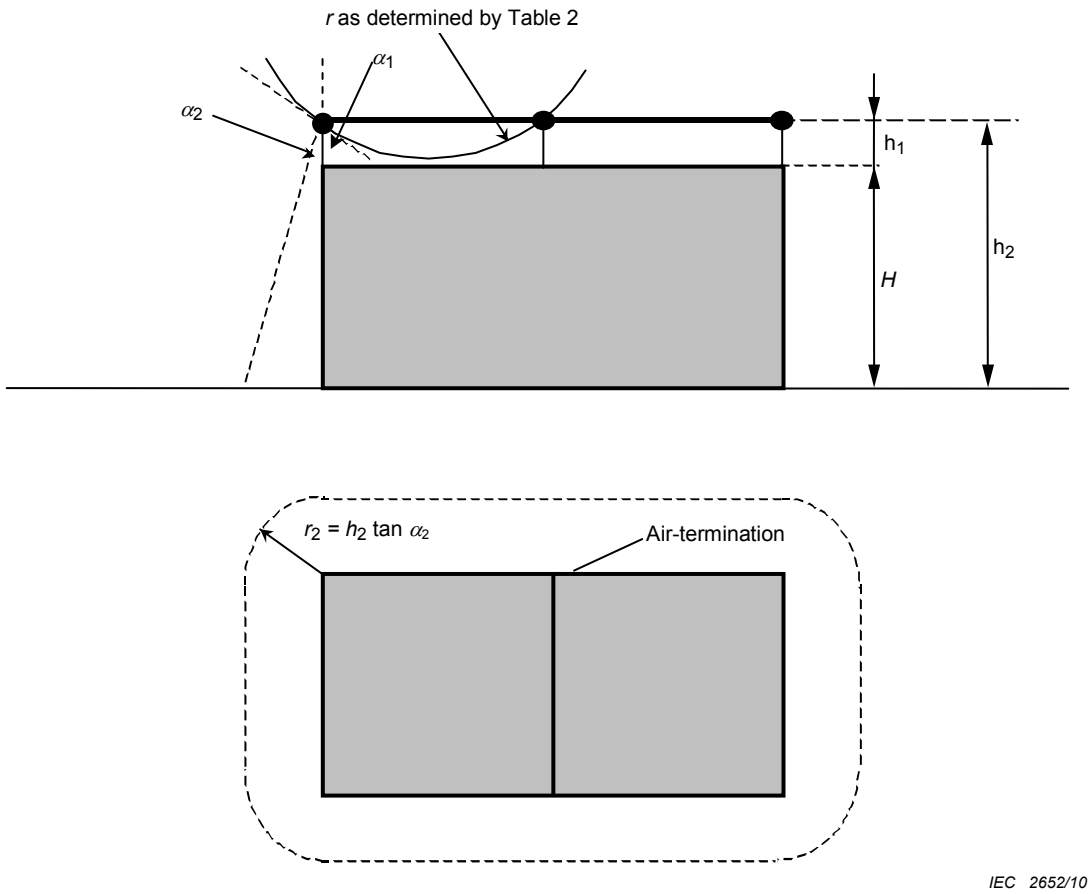

Figure A.4 – Volume protected by isolated wires combined in a mesh according to the protection angle method and rolling sphere method

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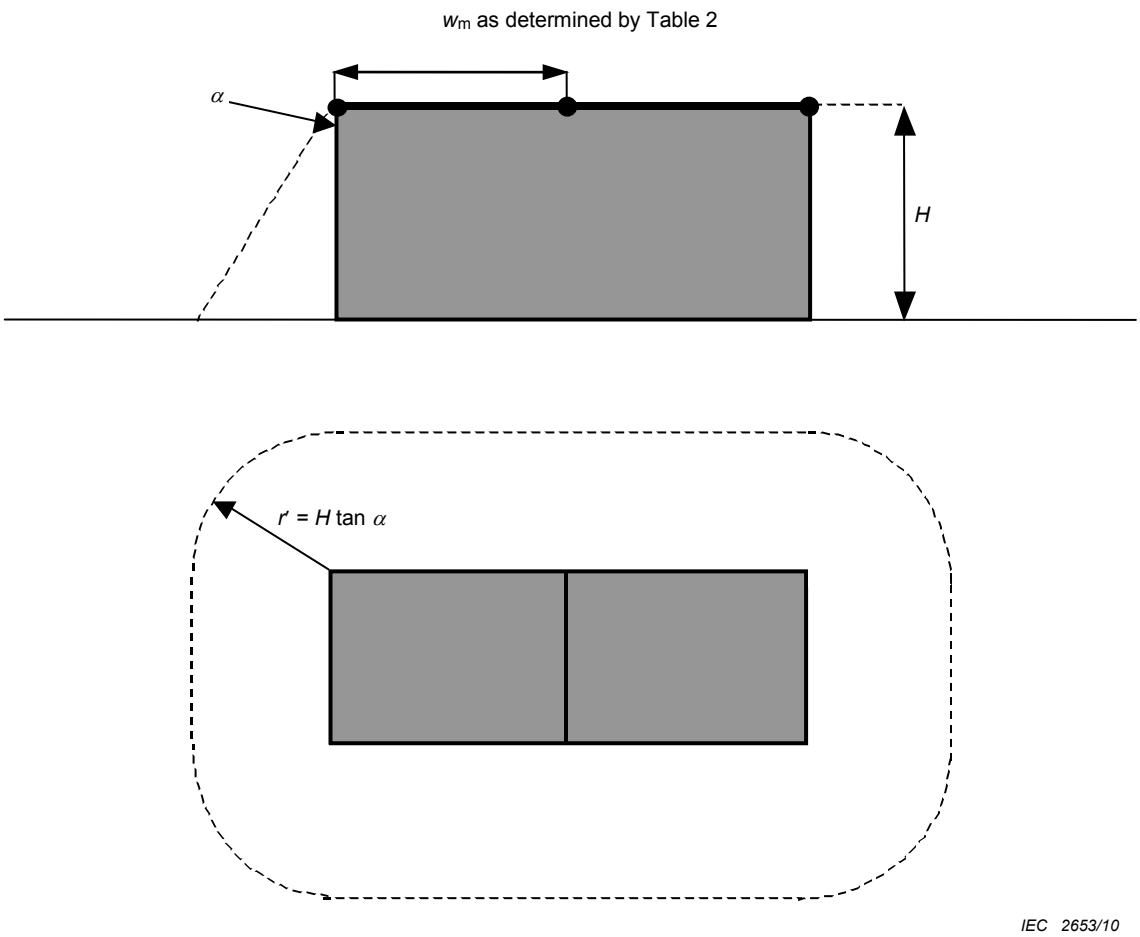

Figure A.5 – Volume protected by non-isolated wires combined in a mesh according to the mesh method and the protection angle method

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).

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.

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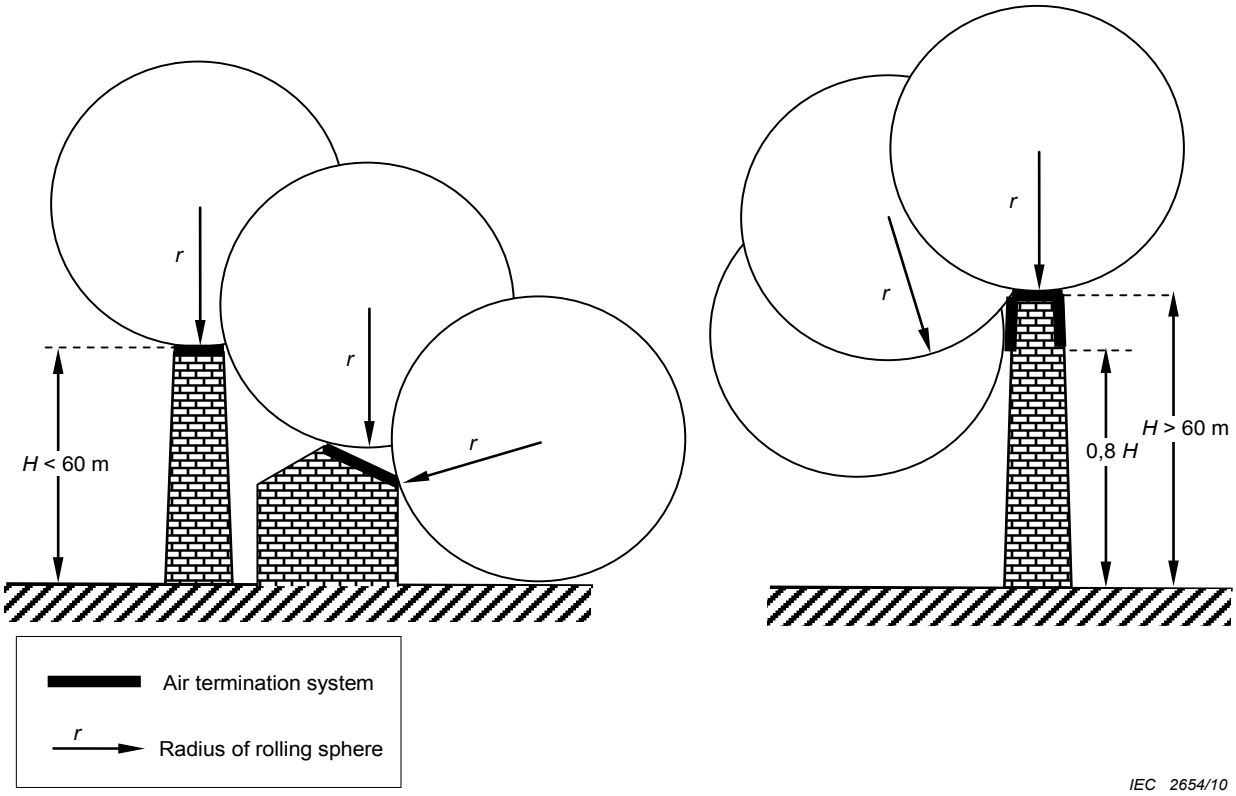

NOTE The rolling sphere radius, *r*, should comply with the selected class of LPS (see Table 2).

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

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 conductors 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.

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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 mm^2) of the cross-sectional area of the screen to avoid dangerous sparking is given by:

$$S_{CMIN} = (I_F \times \rho_C \times L_C \times 10^6) / U_W \quad (\text{mm}^2) \qquad (B.1)$$

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 is the 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 copper 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 mm^2;

S'_C is the cross-section of each conductor, in mm^2.

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Annex C
(informative)

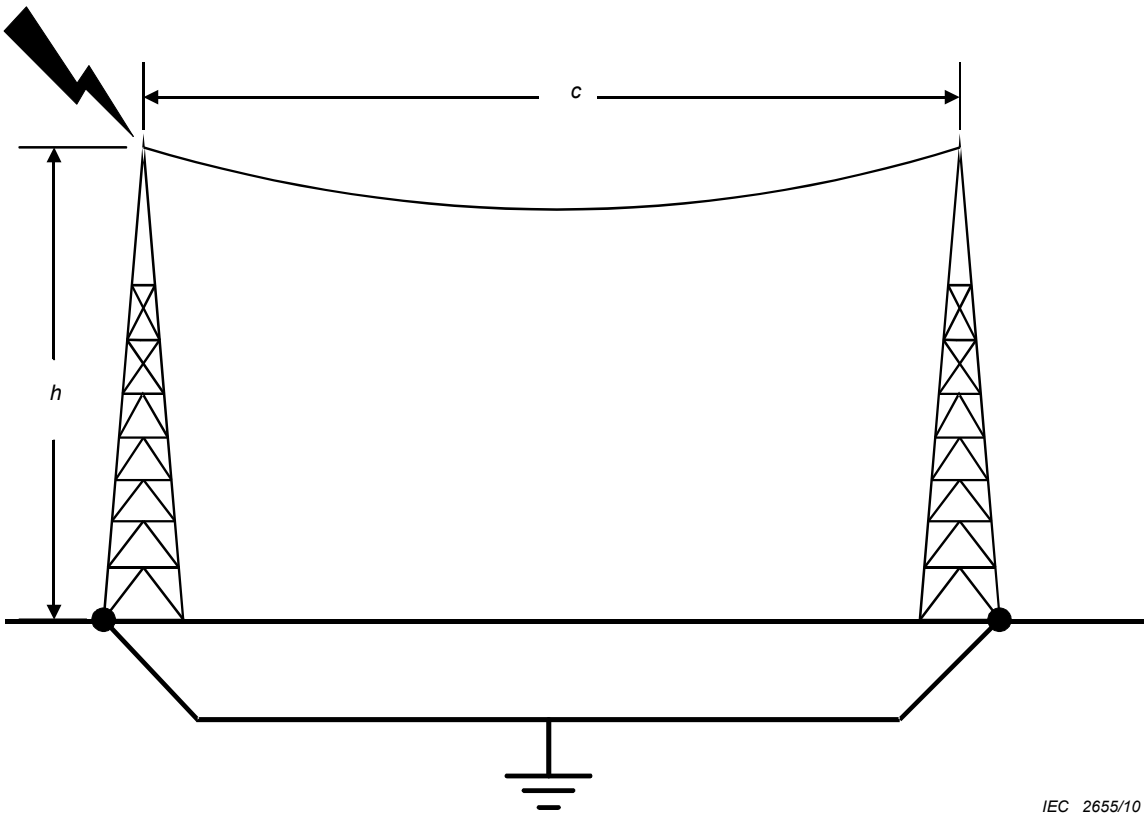
Evaluation of the separation distance *s*

The partitioning coefficient k_c of the lightning current amongst the air-terminations/down-conductors depends on the type of air-termination system, on the overall number, *n*, and on the position of the down-conductors and on the interconnecting ring conductors, and on the type of earth-termination system.

NOTE 1 The necessary separation distance depends on the voltage drop of the shortest path from the point where the separation distance is to be considered, to the nearest equipotential bonding point.

NOTE 2 The information in this annex applies for all type B earthing arrangements and for type A earthing arrangements, provided that the earth resistance of neighbouring earth electrodes do not differ by more than a factor of 2. If the earth resistances of single earth electrodes differ by more than a factor of 2, k_c = 1 is to be assumed.

When the air-terminations or down-conductors have the constant value of current flowing over the lengths of the conductors, Figures C.1, C.2 and C.3 apply (see 6.3.2: Simplified approach).



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

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

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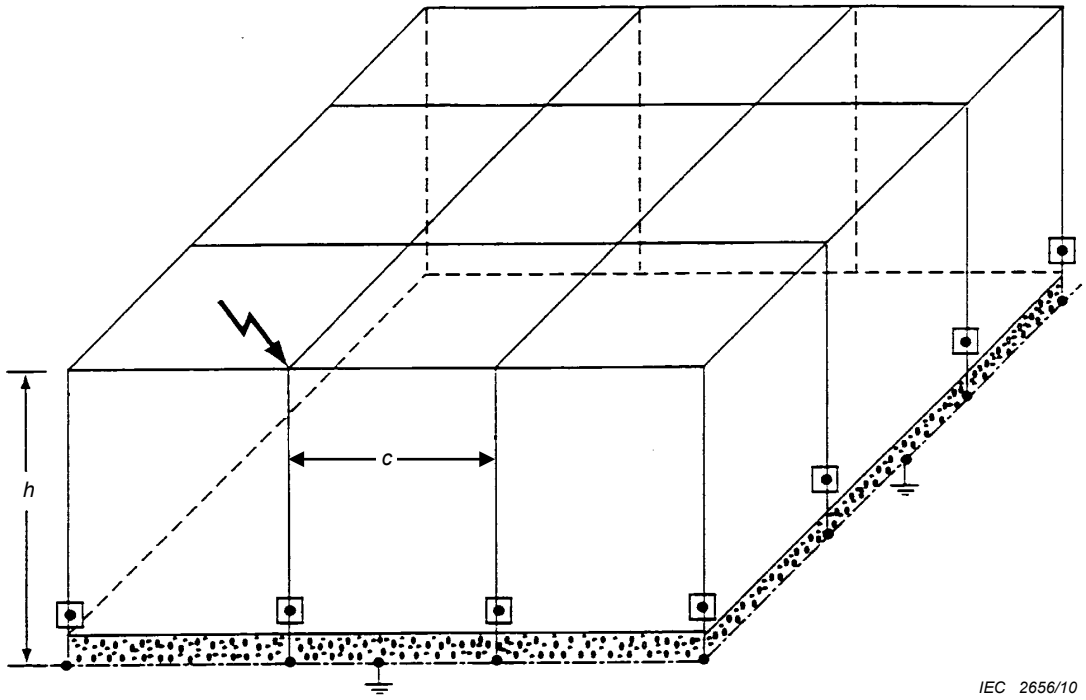

$$k_c = \frac{1}{2n} + 0{,}1 + 0{,}2 \times \sqrt[3]{\frac{c}{h_1}}$$

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 The equation for k_c is an approximation for cubic structures and for $n \geq 4$. The values of *h* and *c* are assumed to be in the range of 3 m to 20 m.

NOTE 2 If internal down-conductors exist, they should be taken into account in the number *n*.

Figure C.2 – Values of coefficient k_c in the case of multiple down-conductors system

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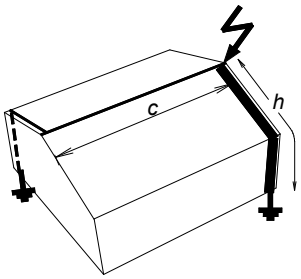
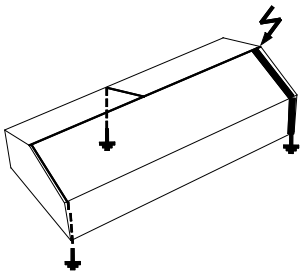
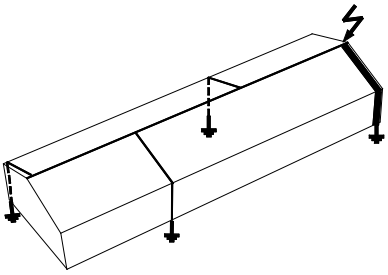
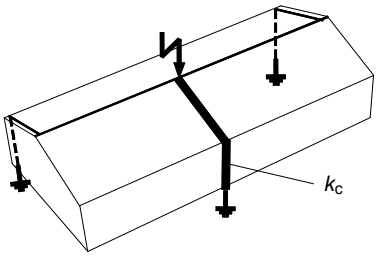
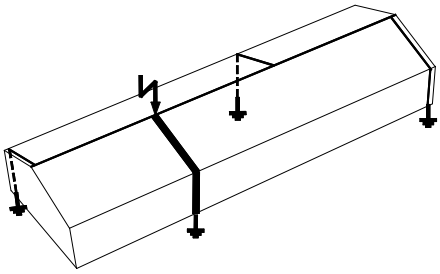
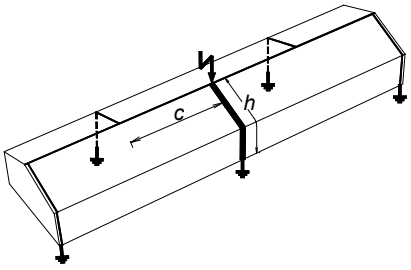
	$\frac{c}{h}$	**0,33**	**0,50**	**1,00**	**2,00**
	k_c	0,57	0,60	0,66	0,75
	k_c	0,47	0,52	0,62	0,73
	k_c	0,44	0,50	0,62	0,73
	k_c	0,40	0,43	0,50	0,60
	k_c	0,35	0,39	0,47	0,59
	k_c	0,31	0,35	0,45	0,58

c Distance from the nearest down-conductor along the ridge

h Length of the down-conductor from the ridge to the next equipotential bonding point or to the earth-termination system

The values of k_c, shown in the table, refer to the down-conductors represented by a thick line and a strike point

The location of the down-conductor (to be considered for k_c) is to be compared with the figure representative for that down-conductor

The actual relation *c*/*h* is to be determined. If this relation ranges between two values in the columns, k_c may be found by interpolation

NOTE 1 Additional down-conductors with more distance than illustrated in the figures are of insignificant influence

NOTE 2 In case of inter-connecting ring-conductors below the ridge see Figure C.4

NOTE 3 The values are determined by simple calculation of parallel impedances following the formula of Figure C.1

Figure C.3 *(continued overleaf)*

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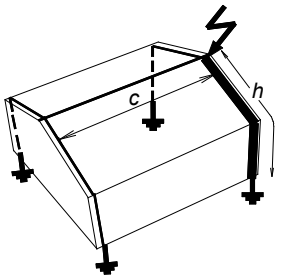
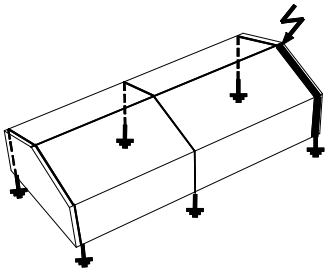
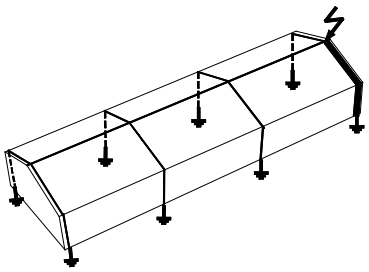
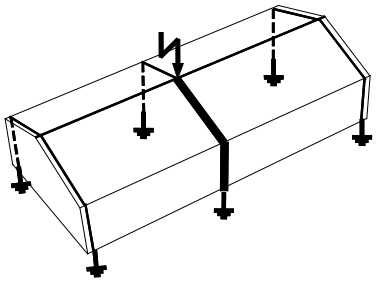
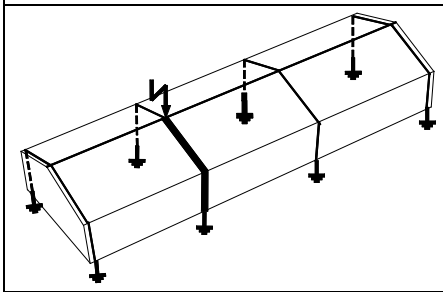
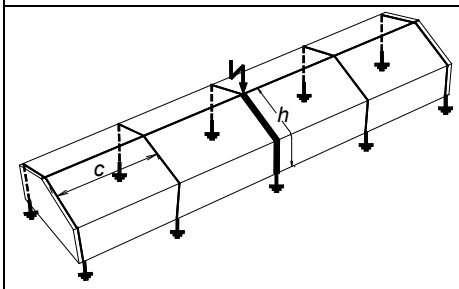
	k_c	0,31	0,33	0,37	0,41	
	k_c	0,28	0,33	0,37	0,41	
	k_c	0,27	0,33	0,37	0,41	
	k_c	0,23	0,25	0,30	0,35	
	k_c	0,21	0,24	0,29	0,35	
	k_c	0,20	0,23	0,29	0,35	

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Figure C.3 – Values of coefficient k_c in the case of a sloped roof with air-termination on the ridge

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$$d_a \geq s_a = \frac{k_i}{k_m} \times k_{c1} \times l_a$$

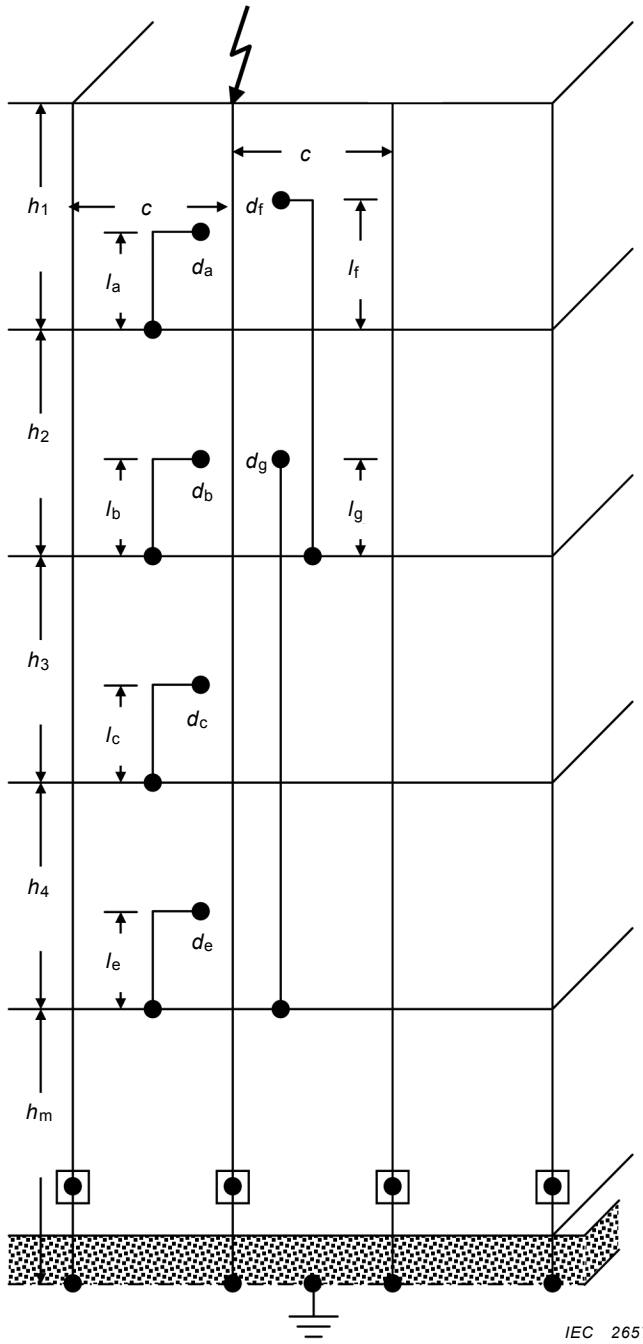
$$d_b \geq s_b = \frac{k_i}{k_m} \times k_{c2} \times l_b$$

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

$$d_e \geq s_e = \frac{k_i}{k_m} \times k_{c4} \times l_e$$

$$d_f \geq s_f = \frac{k_i}{k_m} \times (k_{c1} \times l_f + k_{c2} \times h_2)$$

$$d_g \geq s_g = \frac{k_i}{k_m} \times (k_{c2} \times l_g + k_{c3} \times h_3 + k_{c4} \times h_4)$$



$$k_{c1} = \frac{1}{2n} + 0{,}1 + 0{,}2 \times \sqrt[3]{\frac{c}{h_1}}$$

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

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

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

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

Key

n	total number of down-conductors
c	spacing between down-conductors
h	spacing (height) between ring conductors
m	total number of levels
d	distance to the nearest down-conductor
l	height above the bonding point

NOTE If internal down-conductors exist, they should be taken into account in the number *n*.

Figure C.4 – Examples of calculation of the separation distance in the case of multiple down-conductors with an interconnecting ring of the down-conductors at each level

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