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PROTECTION OF STRUCTURES AGAINST LIGHTNING –

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FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation 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. 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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3) The documents produced have the form of recommendations for international use and are published in the form of standards, technical reports or guides and they are accepted by the National Committees in that sense.

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6) Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. The IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 61024-1-2 has been prepared by IEC technical committee 81: Lightning protection.

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

FDIS	Report on voting
81/109/FDIS	81/112/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.

Annexes A and B form an integral part of this standard.

In this standard the following print types are used:

– Requirements: in roman type;

– Explanatory matter: in small roman type.

INTRODUCTION

IEC 61024-1 establishes the fundamental definitions and general principles of lightning protection and provides the necessary information concerning design, construction and materials to facilitate the management and basic installation of external and internal lightning protection systems (LPS) for common structures. It also gives basic requirements and instructions for good maintenance and inspection practice of LPS.

The selection of protection levels for lightning protection systems is covered by Guide A of IEC 61024-1-1.

Guide B complements IEC 61024-1 by giving the consensus view of many countries' experts as to the best general practice based on the present state of the art concerning design, construction, maintenance and testing of LPS.

Table 1 of this guide facilitates the management of LPS design so that LPS are integrated into structures at minimum cost.

Flow diagram (figure 1) facilitates systematic and rational consideration of the design by establishing a time-efficient procedure.

This guide is used in conjunction with Part 1, when the particular aspects of protection assessment and physical design and construction of an LPS are considered.

PROTECTION OF STRUCTURES AGAINST LIGHTNING –

Part 1-2: General principles – Guide B – Design, installation, maintenance and inspection of lightning protection systems

1 General

1.1 Scope and object

This part of IEC 61024 serves as a guide and is applicable to the design and installation of LPS for common structures up to 60 m high, in accordance with IEC 61024-1.

This guide provides guidelines on how to use IEC 61024-1 and assists the user with the physical design and construction, maintenance and inspection of an LPS in accordance with that standard.

Examples are given of protection techniques which have the approval of international experts.

NOTE – The examples given illustrate one possible method of achieving protection. Other methods may be equally valid.

1.2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 61024. At the time of publication, the editions indicated were valid. All normative documents are subjected to revision, and parties to agreements based on this part of IEC 61024 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60364 (all parts), *Electrical installations of buildings*

IEC 61024-1:1990, *Protection of structures against lightning – Part 1: General principles*

IEC 61024-1-1:1993, *Protection of structures against lightning – Part 1: General principles – Section 1: Guide A – Selection of protection levels for lightning protection systems*

IEC 61312-1:1995, *Protection against lightning electromagnetic impulses – Part 1: General principles*

IEC 61662:1995, *Assessment of the risk of damage due to lightning*

1.3 Terms and definitions

For the purpose of this part of IEC 61024, and in addition to the terms and definitions given in IEC 61024-1, the following definitions apply:

1.3.1
lightning protection designer
specialist competent and skilled in the design of the LPS

NOTE – The functions of LPS designer and installer may be performed by the same person.

1.3.2
lightning protection installer
a person competent and skilled in the installation of LPS

NOTE – The functions of LPS designer and installer may be performed by the same person.

1.3.3
ring conductor
conductor forming a loop around the structure and interconnecting the down conductors for an equal distribution of lightning current among them

1.3.4
external conductive parts
extended metal items entering or leaving the structure to be protected such as: pipe networks, cable screens, metal ducts, etc. which may carry a part of the lightning current

1.3.5
surface resistivity
average resistivity of the surface layer of the soil

1.3.6
corrosion of metals
all types of corrosion, galvanic and chemical

1.3.7
striking distance
adopted radius of the rolling sphere as given in table 1 of IEC 61024-1

1.3.8
internal down-conductor
down-conductor situated inside the structure protected against lightning; for example a column of reinforced concrete used as a natural down-conductor

1.3.9
steel bonding bar
common steel rod tied to the reinforcing bars with steel wires of a reinforced concrete structure to which bonding conductors or other interconnecting conductors are welded or clamped

1.3.10
steel bonding connector
connection used for the steel rods which are lashed to the reinforcing rods and which are employed for connection of the equipotential bonding inside the building to the reinforcing rods and thus distribute the introduced current among the reinforcing rods

1.3.11
bonding conductor
conductor for connections between parts to be connected to the potential bonding bar and for the connections to the bonding connectors. These lie in part outside the concrete (from the parts to be connected to the connection point), in part within the concrete (between the connection point and the bonding connector) (see also 1.2.20 of IEC 61024-1, modified)

1.3.12
bonding bar
bar by means of which the bonding conductors are interconnected (mutually connected) (see also 1.2.19 of IEC 61024-1, modified)

1.3.13
vertical earth electrode
earth electrode installed in soil in a vertical position or with an inclination to the vertical

2 Design of lightning protection systems (LPS)

2.1 General remarks

The primary function of an LPS designed in accordance with IEC 61024-1 is to protect lives and property from the destructive effects of lightning.

The LPS should be designed and installed by LPS designers and installers.

The lightning protection designer should be capable of assessing both the electrical and mechanical effects of lightning discharge and also be familiar with the general principles of electromagnetic compatibility (EMC), see table 1.

Furthermore the lightning protection designer should be capable of assessing corrosion effects and judging when it is necessary to seek expert assistance.

The lightning protection installer should be trained in the proper installation of the LPS components in accordance with the requirements of IEC 61024-1 and the national rules regulating construction work and the building of structures.

Planning, implementation and testing of the LPS covers a number of technical fields and makes demands for coordination by all parties involved with the structure to ensure the achievement of the selected lightning protection level with minimum cost and lowest possible effort. The management of the LPS should be efficient if the steps in table 1 are followed. The quality assurance measures are of great importance in particular for structures including extensive electrical and electronic installations.

The quality assurance measures extend from the planning stage, in which all drawings should be approved, through the LPS construction stage during which all essential parts of the LPS which will not be accessible for inspection after the construction works have been finished should be checked, through the acceptance stage when final measurements on the LPS should be performed together with the accomplishment of the final test documentation and finally through the entire life time of the LPS by specifying careful periodic inspections in accordance with the maintenance programme.

The LPS should be maintained regularly to ensure that it does not deteriorate but continues to fulfil the requirements to which it was originally designed.

The LPS maintenance programme should ensure a continuous updating of the LPS.

Where modifications are made to a structure or its installations, a check should be made to determine whether the existing lightning protection still complies with IEC 61024-1. If it is found that the protection is inadequate, improvements should be implemented immediately.

It is recommended that the materials, extent and dimensions of the air terminations, down conductors, earth terminations, bonding, components, etc. as laid down in this standard should be adhered to in full, irrespective of any devices or systems employed which are claimed to provide enhanced protection (see 2.1.3 of IEC 61024-1).

2.2 Planning procedure

Before any detailed design work on the LPS is commenced, the lightning protection designer should obtain basic information regarding the function, general design, construction and location of the structure.

Where the LPS has not already been specified by the licensing authority, insurer or purchaser, the lightning protection designer should classify the structure in accordance with clause 2 of IEC 61024-1-1 and determine whether or not to protect the structure with an LPS by following the procedures in clause 4 of IEC 61024-1-1, for selection of proper LPS protection level.

When the structure has been classified as being common and a protection level has been determined, the lightning protection designer should use IEC 61024-1, with the relevant application guides – IEC 61024-1-1 (guide A) and this standard (guide B) – to design a comprehensive LPS.

The construction and installation of the LPS should be supervised by an LPS installer.

2.3 Consultation

2.3.1 General information

In the design and construction stages of a new structure, the LPS designer and LPS installer and all other persons responsible for installations in the structure or for regulations pertaining to the use of the structure (e.g. purchaser, architect civil constructor) should consult each other regularly.

The flow diagram of figure 1 will facilitate the rational design of an LPS.

In the design and construction stages of an LPS for an existing structure, consultations should be held with the persons responsible for the structure, its use, installations and incoming services.

The consultations may have to be arranged through the owner or the building contractor for the structure or their appointed representative. For existing structures the LPS designer should provide drawings which should be modified by the LPS installer, where necessary.

Regular consultations between the involved parties should result in an effective LPS at the lowest possible cost. For example, the coordination of LPS design work and construction work will often obviate the need for some bonding conductors and reduce the length of those which are necessary. Building costs are often reduced substantially by the provision of common routes for various installations within a structure.

Consultation is important throughout all stages of the construction of a structure as modifications to the LPS may be required due to changes in the structure design. Consultation is also necessary so that arrangements can be agreed to facilitate inspection of the parts of the LPS which will become inaccessible for visual control after the structure is completed. In these consultations all locations should be determined at which connections between natural components and the LPS will be required. Architects are normally available to arrange and coordinate consultation meetings for new building projects.

2.3.2 The principal consulting parties

The lightning protection designer should hold relevant technical consultations with all parties involved in the design and construction of the structure including the owner of the structure.

Particular areas of responsibility for the total installation of the LPS should be defined by the LPS designer in conjunction with the architect, building contractor and the LPS installer (LPS supplier) and, where relevant a historical adviser and the owner or his representative.

The clarification of responsibility for the various parties involved in the management of the design and construction of the LPS is of particular importance. An example might be where the waterproofing of the structure is punctured by roof-mounted LPS components or by earth electrode connection conductors made below the structure foundation.

2.3.2.1 Architect

Agreement should be reached on the following items:

- routing of all LPS conductors;
- materials for LPS components;
- details of all metal pipes, rain-water systems, rails and similar items;
- details of any equipment, apparatus, plant installations or the like to be installed within or near the structure and which may require bonding to the LPS. Examples of installations are alarm systems, security systems, internal telecommunication systems, signal and data processing systems, radio and TV circuits;
- extent of any buried conductive service which could affect the positioning of the earth termination network and be required to be placed at a safe distance from the LPS;
- general area available for the earth-termination network;
- extent of the work and the division of responsibility for primary fixings to the structure of the LPS. For example, those affecting the water tightness of the fabric, chiefly roofing;
- conductive materials to be used in the structure, especially any continuous metal, which may have to be bonded to the LPS, for example stanchions, reinforcing, and metal services either entering or leaving the structure or within the structure;
- visual impact of the LPS;
- impact of the LPS on the fabric of the structure;
- the location of the connection points to the reinforcing steel, especially at penetration of external conductive parts (pipes, cable shields, etc.).

2.3.2.2 Public utilities

Agreement should be reached regarding the acceptability of bonding to LPS of incoming services. Agreements made for other structures should not be relied on.

2.3.2.3 Fire and safety authorities

Agreement should be reached on the following items:

- positioning of alarm and fire extinguishing system components;
- routes, construction material and sealing of ducts;
- in the case of a structure having a flammable roof, the method of protection should be agreed.

2.3.2.4 Electronic system and external antenna installers

Agreement should be reached on the following items:

- bonding aerial supports and conductive shields of cables to the LPS;
- routing of aerial cables and internal network and installation of devices for common use;
- installation of surge protective devices.

2.3.2.5 Builder and installer

Agreement should be reached on the following items with those responsible for construction of the structure and its technical equipment:

- form, position and number of primary fixings of the LPS to be provided by the builder;
- any fixings provided by the LPS designer (or the LPS contractor or the LPS supplier) to be installed by the builder;
- position of LPS conductors to be placed beneath the structure;
- whether any components of the LPS are to be used during the construction phase, for example the permanent earth-termination network could be used for earthing cranes, hoists and other metallic items during construction work on the site;
- for steel-framed structures, the number and position of stanchions and the form of fixing to be made for the connection of earth terminations and other components of the LPS;
- whether metal coverings, where used, are suitable as components of the LPS;
- where metal coverings are suitable as components of the LPS, the method of ensuring the electrical continuity of the individual parts of the coverings and their method of connecting them to the rest of the LPS;
- nature and location of services entering the structure above and below ground including conveyor systems, television and radio aerials and their metal supports, metal flues and window cleaning gear;
- coordination of the structure's LPS earth-termination system with the bonding of power and communication services;
- position and number of flag masts, roof level plant rooms; for example lift motor rooms, ventilation, heating and air-conditioning plant rooms, water tanks and other salient features;
- construction to be employed for roofs and walls in order to determine appropriate methods of fixing LPS conductors, specifically with a view to maintaining the water-tightness of the structure;
- provision of holes through the structure to allow free passage of LPS down-conductors;
- provision of bonding connections to steel frames, reinforcement bars and other conductive parts of the structure;
- frequency of inspection of LPS components which will become inaccessible; for example steel reinforcing bars encapsulated in concrete;
- most suitable choice of metal for the conductors taking account of corrosion, especially at the point of contact between dissimilar metals;
- accessibility of test joints, provision of protection by non-metallic casings against mechanical damage or pilferage, lowering of flag masts or other movable objects, facilities for periodic inspection especially for chimneys;
- preparation of drawings incorporating the above details and showing the positions of all conductors and main components;
- location of the connection points to the reinforcing steel.

2.4 Design of an external LPS

2.4.1 General information

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

An isolated external LPS should be used when the flow of the lightning current into bonded internal conductive parts may cause damage to the structure.

NOTE – Typical cases are areas with danger of explosion and fire.

When the thermal effects on the point of strike or on conductors carrying the lightning current may cause damage to the structure or to the content of the volume to be protected, the spacing between LPS conductors and flammable material should be at least 0,1 m.

NOTE 1 – Typical cases are:

– structures with combustible covering;

– structures with combustible walls.

NOTE 2 – The use of an isolated LPS may be convenient where it is predicted that changes in the structure may cause modifications to the LPS.

Dangerous sparking between LPS and metal, electrical and telecommunication installations can be avoided:

– in isolated LPS by insulation or separation according to 3.2 of IEC 61024-1;
– in non-isolated LPS by equipotential bonding, according to 3.1 of IEC 61024-1, or by insulation or separation according to 3.2 of IEC 61024-1.

The positioning of external LPS conductors is fundamental to the design of the LPS and depends on the shape of the structure to be protected, the level of protection required and the geometric design method employed. The air-termination design generates the protected space of the structure and generally dictates the design of the down-conductor, the earth-termination system and the design of the internal LPS.

2.4.2 Design of the air-termination system

2.4.2.1 General

The arrangement of an air-termination system should fulfil the requirements of table 1 of IEC 61024-1.

For the design of the air-termination system the following methods should be used, independently or in any combination, provided that the zones of protection afforded by different parts of the air termination overlap and ensure that the structure is entirely protected according to 2.1.2 of IEC 61024-1:

– protective angle method;
– rolling sphere method;
– mesh size method.

All three methods may be used for the design of an LPS. The choice of a certain type of LPS depends on a practical evaluation of its suitability and the vulnerability of the structure to be protected.

The protection method may be selected by the LPS designer. However, the following considerations may be valid:

– the protective angle method is suitable for simple structures or for small parts of bigger structures. This method is not suitable for structures higher than the radius of the rolling sphere relevant to the selected protection level of the LPS;
– the rolling sphere method is suitable for complex shaped structures;
– the mesh method is for general purpose and it is particularly suitable for the protection of plane surfaces.

The air-termination design method and LPS design methods used for the various parts of the structure should be explicitly stated in the design documentation.

2.4.2.2 Protective angle method

Air-termination conductors, rods, masts and wires, should be positioned so that all parts of the structure to be protected are inside the envelope surface generated by projecting points on the air-termination conductors to the reference plane, at an angle α to the vertical in all directions.

The protective angle α should comply with IEC 61024-1, table 1, h being the height of the air-termination above the surface to be protected.

A single point generates a cone. Figures 2 and 3 of this standard show how protected space is generated by the LPS's different air-termination conductors.

According to IEC 61024-1, table 1, the protective angle α is different for different heights of air-termination above the surface to be protected (see figure 4).

The protective angle method has geometrical limits and shall not be applied if h is larger than the rolling sphere radius R as defined in table 1 of the IEC 61024-1.

The design of air-terminations using the protective angle air-termination design method is also shown in figures 5, 6 and 7 for an isolated LPS and in figures 8, 9 and 10 for a non-isolated LPS, respectively.

2.4.2.3 Rolling sphere method

The rolling sphere method should be used to identify the protected space of parts and areas of a structure when table 1 of IEC 61024-1 excludes the use of the protective angle method.

Applying this method, the positioning of an air-termination system is adequate if no point of the space to be protected is in contact with a sphere with radius R rolling on the ground, around and on to top of the structure in all possible directions. Therefore the sphere shall touch only the ground and/or the air-termination system.

The radius of the rolling sphere should comply with the selected protection level of the LPS according to the IEC 61024-1, table 1.

Figures 11, 12 and 13 show the application of the rolling sphere method to different structures. The sphere of radius R is rolled around and over all the structure until it meets the ground plane or any permanent structure or object in contact with the earth plane which is capable of acting as a conductor of lightning. Where the rolling sphere touches the structure, a strike could occur and at such points protection by an air-termination conductor is required.

When the rolling sphere method is applied to drawings of the structure, the structure should be considered from all directions to ensure that no part protrudes into an unprotected zone, a point which might be overlooked if only front, side and plan views on drawings are considered.

The protected space generated by an LPS conductor is the volume not penetrated by the rolling sphere when it is in contact with the conductor and applied to the structure.

Figure 14 shows the protection afforded by an air-termination rod or mast with a physical height, $h_t = h$, which is less than the radius R of the rolling sphere or a point A on an LPS horizontal air-termination conductor at a physical height, $h_t = h$, from the plane of reference.

When the applied height h, in IEC 61024-1, table 1, is greater than rolling sphere radius R the protection afforded by the air-termination rod or point on a horizontal air-termination conductor is restricted to the structure below point B as indicated in figure 15.

Another horizontal air-termination conductor should be placed at level B and an air-termination is required at point C if it is a part of the structure to be protected.

In the case of two parallel horizontal LPS air-termination conductors placed above the horizontal reference plane in figure 16, the penetration distance p of the rolling sphere below the level of the conductors in the space between the conductors should be calculated:

$$p = R - [R^2 - (d/2)^2]^{1/2}$$

The penetration distance p should be less than h_t.

The example shown in figure 16 is also valid for three or four air-termination rods. For example, four vertical rods placed at the corners of a square and having the same applied height h. In this case, d in figure 16 corresponds to the diagonals of the square formed by the four rods.

2.4.2.4 Mesh method

For the purpose of protecting flat surfaces, a mesh is considered to protect the whole surface if the following conditions are fulfilled:

a) air termination conductors are positioned on:
   - roof edge lines,
   - roof overhangs,
   - roof ridge lines, if the roof slope exceeds 1/10;

b) the lateral surfaces of the structure at levels higher than the value of the radius of the relevant rolling sphere (see table 1), is equipped with air-termination systems;

c) the mesh dimensions of the air-termination network are not greater than the values given in table 1;

d) the network of the air-termination system is accomplished in such a way that the lightning current will always encounter at least two distinct metal routes to the earth air-termination; no metal installation protrudes outside the volume protected by air-termination systems;

e) the air-termination conductors follow as far as possible short and direct routes;

NOTE – Examples of a non-isolated LPS using the air-termination mesh method design are shown in figure 17b for a sloped-roof structure and in figure 17a for a flat-roof structure.

2.4.2.5 Choice of the type of air-termination system

IEC 61024-1 does not provide any criteria for the choice of the air-termination system because it considers rods, stretched wires and meshed conductors as equivalent.

It is possible to say that:

- an air-termination system composed of rods is preferred for an isolated LPS and for simple structures of small dimensions or for small parts of large structures. The height of non-isolated rods should be less than a few metres (2 m to 3 m) in order to avoid any increase in frequency of direct lightning flash. The rods are not suitable for structures higher than the radius of the rolling sphere relevant to the selected protection level of the LPS;
- an air-termination system composed of stretched wires can be preferred in all previous cases and for short, long shaped structures ($a / b \geq 4$);
- air termination systems composed of meshed conductors are for general purpose.

2.4.3 Design of down-conductors

2.4.3.1 General data

The choice of number and position of down-conductors should take into account the fact that, if the lightning current is shared in several down-conductors, the risk of side flash and of electromagnetic disturbances inside the structure is reduced. It follows that, as far as possible, the down-conductors should be uniformly placed along the perimeter of the structure and with a symmetric configuration.