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Partie 1:
Principes généraux

Protection against lightning electromagnetic impulse –

Part 1:
General principles

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

PROTECTION AGAINST LIGHTNING ELECTROMAGNETIC IMPULSE –

Part 1: General principles

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 cooperation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. 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.

2) The formal decisions or agreements of the IEC on technical matters, prepared by technical committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.

3) They have the form of recommendations for international use published in the form of standards, technical reports or guides and they are accepted by the National Committees in that sense.

4) In order to promote international unification, IEC National Committees undertake to apply IEC International Standards transparently to the maximum extent possible in their national and regional standards. Any divergence between the IEC Standard and the corresponding national or regional standard shall be clearly indicated in the latter.

International Standard IEC 1312-1 has been prepared by IEC technical committee 81: Lightning protection.

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

DIS	Report on voting
81(CO)21	81/66/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.

IEC 1312-1 forms part of a series of publications under the general title: *Protection against lightning electromagnetic impulse.*

Annexes A, B, C, D and E are for information only.

INTRODUCTION

The need for this International Standard has arisen from the increasing use of many types of electronic systems including computers, telecommunication equipment, control systems, etc. (referred to in this standard as information systems). Such systems are used in many branches of commerce and industry, including controlling process plants of considerable capital cost, size and complexity, for which lightning induced outages are very undesirable for cost and safety reasons.

For the general principles of the protection of structures against lightning, IEC 1024-1 is available. However, this main standard does not cover protection of electric and electronic systems. This lightning electromagnetic impulse (LEMP)[1] standard, therefore, provides a basis for system protection, and supplements the existing standard.

Solid state devices are more susceptible to lightning surges than previously used components. Moreover, computers are being designed to give very comprehensive control of very complicated process plants in order to simplify the task for the human operators and to allow for automatic process optimization. Computers also undertake safety functions, for example, the safety systems on nuclear reactors.

Lightning as a source of interference is a very high energy phenomenon. Lightning strokes release many hundreds of mega-joules of energy, which may be contrasted with perhaps an order of magnitude of milli-joules, which might affect sensitive electronics. A rational engineering approach to protection is required therefore. This standard attempts to explain the lightning coupling mechanism during transients and gives principles for reducing transient interference into information systems such as electronic systems.

[1] The abbreviation LEMP will be used in this standard.

PROTECTION AGAINST LIGHTNING ELECTROMAGNETIC IMPULSE –

Part 1: General principles

1 General

1.1 *Scope and object*

This part of IEC 1312 provides information for the design, installation, inspection, maintenance and testing of an effective lightning protection system for information systems in or on a structure.

The following cases are outside the scope of this standard: vehicles, ships, aircraft, and offshore installations are covered by regulations made by specific authorities.

The system equipment itself is not considered in this standard. However the content provides guidelines for the co-operation between the designer of the information system and the designer of the protection system against LEMP in order to achieve optimum protection effectiveness.

1.2 *Normative reference*

The following normative document contains provisions which, through reference in this text, constitute provisions of this part of IEC 1312. At the time of publication, the edition indicated was valid. All normative documents are subject to revision, and parties to agreements based on this part of IEC 1312 are encouraged to investigate the possibility of applying the most recent edition of the normative document indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 1024-1: 1990, *Protection of structures against lightning – Part 1: General principles*

1.3 *Terms and definitions*

For the purpose of this part of IEC 1312 the following definitions apply, as well as those given in IEC 1024-1:

1.3.1 **bonding network:** Network of conductors bonding the exposed conductive parts of a system.

1.3.2 **common earthing system:** All interconnected metal installations of a structure, including external lightning protection systems (LPS), connected to the earth termination system.

1.3.3 **earthing reference points (ERP):** The only connecting point between the common earthing system and the bonding network of system.

1.3.4 **environmental zone:** Zone where electromagnetic conditions are defined.

1.3.5 **equipotential bonding:** Connections defined in IEC 1024-1 and made by means of bonds or surge suppressors as described in 3.1.1 of IEC 1024-1.

1.3.6 **lightning current:** Current at the point of strike.

1.3.7 **lightning electromagnetic impulse (LEMP):** Current and fields of lightning magnetic impulse as a source of interference.

1.3.8 **lightning protection zone (LPZ):** Zones where lightning electromagnetic environment is to be defined and controlled.

1.3.9 **local bonding bar:** Bonding bar at the boundary of subsequent zones.

1.3.10 **long duration stroke:** Stroke with duration (time from the 10 % value in the front to the 10 % value in the tail) of the current is more than some 10 ms and less than 1 s (see figure 1).

1.3.11 **short duration stroke:** Stroke with time to the half stroke value in the tail of the current less than 1 ms (see figure 1).

1.3.12 **surge protection device (SPD):** Device to suppress line conducted overvoltages and currents, such as surge suppressors defined in IEC 1024-1, including also gaps, varistors, diodes, filters, etc.

2 Source of interference

2.1 *Lightning current as source of interference*

For the purposes of analytical estimation of current distribution in the LPS and bonded installations, the lightning current source shall be considered as a current generator injecting a lightning current, consisting of several strokes, into the conductors of the LPS and its bonded installations.

This conducted current, as well as the current in the lightning channel, causes electromagnetic interferences. The electromagnetic coupling processes are explained in annex D.

2.2 *Lightning current parameters*

For simulation purposes, it shall be assumed that the lightning current consists, according to the individual strokes in a flash (figure 2), of

- a first stroke of positive or negative polarity,
- a subsequent stroke of negative polarity;
- a long duration stroke of positive or negative polarity.

The lightning current parameters at the point of strike for various protection levels are given in:

- table 1 for the first stroke;
- table 2 for the subsequent stroke;
- table 3 for the long duration stroke.

For definitions, see figure 1.

For the background of the fixed lightning current parameters, see annex A.

The time function of the lightning current to be used for analysis purposes is given in annex B.

The simulation of the lightning current to be used for test purposes is described in annex C.

3 Lightning protection zones

The volume to be protected shall be divided into lightning protection zones (LPZ) to define volumes of different LEMP severities, and to designate locations for bonding points on the zone boundaries.

Zones will be characterized by significant changes of the electromagnetic conditions at their boundaries.

3.1 *Zone definitions*

LPZ 0_A: Zone where items are subject to direct lightning strokes, and therefore may have to carry up to the full lightning current. The unattenuated electromagnetic field occurs here.

LPZ 0_B: Zone where items are not subject to direct lightning strokes, but the unattenuated electromagnetic field occurs.

LPZ 1: Zone where items are not subject to direct lightning strokes and where currents on all conductive parts within this zone are further reduced compared with zones 0_B. In this zone the electromagnetic field may also be attenuated depending on the screening measures.

Subsequent zones (LPZ 2, etc.):
If a further reduction of conducted currents and/or electromagnetic field is required, subsequent zones shall be introduced. The requirement for those zones shall be selected according to the required environmental zones of the system to be protected.

In general, the higher the number of the zones, the lower the electromagnetic environment parameters.

At the boundary of the individual zones, bonding of all metal penetrations shall be provided and screening measures might be installed.

NOTE – Bonding at the boundary between LPZ 0_A, LPZ 0_B and LPZ 1 is defined in 3.1 of IEC 1024-1.

The electromagnetic fields inside a structure are influenced by openings such as windows, by currents on metal conductors (e.g. bonding bars, cable shields and tubes), and by cable routing.

The general principle for the division of a volume to be protected into different lightning protection zones is shown in figure 3.

Figure 4 shows an example for dividing a structure into several zones. Here all electric power and signal lines enter the protected volume (LPZ 1) at one point, and are bonded to bonding bar 1 at the boundary of LPZ 0_A, LPZ 0_B and LPZ 1. In addition, the lines are bonded to the internal bonding bar 2 at the boundary of LPZ 1 and LPZ 2. Furthermore, the outer shield 1 of the structure is bonded to bonding bar 1 and the inner shield 2 to bonding bar 2. Where cables pass from one LPZ to another, the bonding must be executed at each boundary. LPZ 2 is constructed in such a way that partial lightning currents are not transferred into this volume and cannot pass through it.

3.2 *Earthing requirements*

Earthing shall comply with IEC 1024-1.

If there are adjacent structures between which power and communication cables pass, the earthing systems shall be interconnected, and it is beneficial to have many parallel paths to reduce the currents in the cables. A meshed earthing system fulfills this requirement.

The lightning current effects are further reduced, e.g., by enclosing all the cables in metal conduits or gridlike reinforced concrete ducts, which must be integrated into the meshed earthing system.

Figure 5 shows a typical example for a meshed earthing configuration for a building with a tower.

3.3 *Shielding requirements*

Shielding effectiveness shall be evaluated by use of the amplitude density of the lightning current, given in figure A6, and of the corresponding amplitude density of the magnetic field.

Shielding is the basic measure to reduce electromagnetic interference.

In figure 6, shielding and routing measures for reduction of induced effects are shown in principle as:

– external shielding measures;
– suitable routing;
– line screening.

These measures can be combined.

In order to improve the electromagnetic environment, all metal parts of significant dimensions associated with the structure shall be bonded together and to the LPS, e.g. metal skin roofs and façades, metal reinforcement of the concrete and metal frames of doors and windows (see figure 7 as an example, where the mesh width is of the order of some tens of centimetres).

Where shielded cables within the volume to be protected are used, their shields shall be bonded at least at both ends, as well as at the LPZ boundaries.

Cables running between separate structures shall be laid inside metal cable ducts, such as metal tubes, grids or gridlike reinforcement in concrete, which shall be conducting from end to end and be bonded to the bonding bars of the separate structures. Cable shields shall be bonded to these bars. Metal cable ducts can be avoided if cable shields are able to carry the foreseeable lightning currents.

3.4 *Bonding requirements*

The purpose of bonding is to reduce potential differences between metal parts and systems inside the volume to be protected against lightning.

Bonding shall be provided and installed at the boundaries of LPZs for the metal parts and systems crossing the boundaries, as well as for metal parts and systems inside a LPZ. Bonding at bonding bars shall be performed by means of bonding conductors and clamps, and, where necessary, by surge protection devices (SPD – see figure 8, where the earth conductor is also bonded).

3.4.1 *Bonding at the boundaries of the lightning protection zones*

3.4.1.1 *Bonding at the boundary between lightning protection zones 0_A, 0_B and 1*

Bonding shall be carried out for all external conductive parts entering the structure.

When the external conductive parts and the electrical power and communication lines enter the structure at different locations, and thus several bonding bars are required, they shall be connected as closely as possible to a ring earth electrode, as well as to the reinforcement and metal façades (see figure 9). If a ring earth electrode has not been provided, these bonding bars shall be connected to individual earth electrodes and interconnected by an internal ring conductor (or a partial ring – see figure 10). For above ground entry of external conductive parts, the bonding bars shall be connected to a horizontal ring conductor inside or outside the wall, which is bonded to the down conductors as well as to the reinforcement, where used (see figure 11).

It is recommended that the external conductive parts as well as the electrical power and communication lines entering the structure at ground level do so at the same location (see figure 12 as an example). This is especially important where the building structure provides little shielding. The bonding bar at the point of entry into the structure shall be connected as closely as possible to the earth electrode, as well as to the reinforcement, where used.

The ring conductor shall be connected to the reinforcement or other shielding elements, such as metal façades, typically every 5 m. For minimum dimensions see table 6 of IEC 1024-1. The minimum cross section for copper or galvanized steel bonding bars shall be 50 mm^2.

Bonding bars for structures which contain information systems where LEMP effects should be minimized, preferably will take the form of a metal plate having multiple connections to the reinforcement or other shielding elements.

For clamps and SPDs used for bonding at the boundary of LPZ 0_A and LPZ 1, the current parameters values according to the tables 1 to 3 should be used, with consideration for current sharing where multiple conductors exist.

For clamps and SPDs used for bonding at the boundary of LPZ 0_B and LPZ 1, the current parameters values shall be evaluated individually.

External conductive parts in LPZ 0_B are expected to carry an induced current, and a small fraction of the lightning current.

For the external conductive parts, as well as the electrical power and communication lines entering the structure at ground level, the partial lightning currents at the point of bonding shall be evaluated. This may be assessed as follows.

Where an individual evaluation is not possible, it can be assumed that 50 % of the total lightning current i enters the earth termination system of the LPS of the structure considered, and 50 % of i, i_s, is distributed among the services entering the structure (external conductive parts, electrical power and communication lines, etc.) The value of the current flowing in each service, i_i, is given by i_s/n, where n is the number of the above mentioned services (see figure 13). For evaluating the current i_v in individual conductors in unscreened cables, the cable current i_i is divided by m, the number of conductors, i.e. $i_v = i_i/m$.

For shielded cables, the current will flow along the shield.

In a domestic property, the telephone line may be disregarded for the calculation of n, as it does not affect the current carried by the other services. Nevertheless, the telephone line shall be bonded, and for the design of the bonding 5 % of the lightning current i shall be assumed as minimum value.

For the cross sections of the bonding conductors, tables 6 and 7 of IEC 1024-1 apply. Table 6 applies, if a proportion of the lightning current ≥25 % flows through the conductive part; table 7 applies, if a proportion of the lightning current <25 % flows through the conductive part.

The SPDs have to withstand partial lightning currents and shall fulfill the additional demands of maximum clamping voltages for surges, and the ability to extinguish "follow-on" currents from the mains.

The maximum surge voltage u_{max} at the entrance of the structure shall be co-ordinated with the withstand capability of the systems involved.

To achieve a sufficiently low value of u_{max}, lines shall be connected to the bonding bar with minimum wire lengths (see figure 14, where u_A and u_L, which do not necessarily appear simultaneously, must be kept below u_{max}).

3.4.1.2 *Bonding at the boundaries between subsequent lightning protection zones*

The general principles for bonding at the boundary between LPZ 0_A , 0_B and 1 are also applicable to subsequent zone boundaries.

All conductive parts, as well as electrical power and communication lines entering a boundary between LPZs, shall be bonded at the boundary. Bonding shall be done via a local bonding bar to which the shielding elements or other local metal works (e.g. equipment cases) are also bonded.

For clamps and SPDs used for bonding, the current parameters shall be evaluated individually. The maximum surge voltages at the boundary of the LPZ shall be co-ordinated with the withstand capability of the systems involved. The SPDs at different zone boundaries shall also be co-ordinated with respect to their energy capabilities.

3.4.2 *Bonding equipment inside the volume to be protected*

3.4.2.1 *Bonding of internal conductive parts*

Bonding for all internal conductive parts of significant dimensions, such as elevator rails, cranes, metal floors, metal door frames, service pipes, cable trays, shall be made to the nearest bonding bar or other bonded metal work by the shortest possible route. Additional multiple interconnection of the conductive parts is advantageous.

Table 7 of IEC 1024-1 applies for the cross-sections of the bonding conductors.

In the bonding elements, only a minor proportion of the lightning current is expected to flow.