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PROTECTION AGAINST LIGHTNING ELECTROMAGNETIC IMPULSE (LEMP) –

Part 2: Shielding of structures, bonding inside structures and earthing

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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- the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC 61312-2, which is a technical specification, has been prepared by IEC technical committee 81: Lightning protection.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
81/105A/CDV	81/127/RVC

Full information on the voting for the approval of this technical specification can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 3.

IEC 61312-2 forms a part of a series of publications under the general title: Protection against lightning electromagnetic impulse (LEMP).

This part 2 supplements the existing part 1 (which sets out general principles), by focussing on the earthing (3.2), shielding (3.3) and bonding requirements (3.4) referred to in clause 3 of IEC 61312-1.

Annexes A, B and C are for information only.

The committee has decided that this publication remains valid until 2005. At this date, in accordance with the committee's decision, the publication will be

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- withdrawn;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

PROTECTION AGAINST LIGHTNING ELECTROMAGNETIC IMPULSE (LEMP) –

Part 2: Shielding of structures, bonding inside structures and earthing

1 General

1.1 Scope and object

This technical specification provides methods for the evaluation of the effectiveness of shielding measures against LEMP for structures with information equipment such as electronic systems in case of direct and nearby lightning strikes. In addition it provides rules for bonding measures inside structures and for earthing methods relating to LEMP.

1.2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 61312. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of IEC 61312 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 61000-4-5:1995, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 5: Surge immunity test*

IEC 61000-4-9:1993, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 9: Pulse magnetic field immunity test. Basic EMC publication*

IEC 61000-4-10:1993, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 10: Damped oscillatory magnetic field immunity test. Basic EMC publication*

IEC 61000-5-2:1997, *Electromagnetic compatibility (EMC) – Part 5: Installation and mitigation guidelines – Section 2: Earthing and cabling*

IEC 61024-1:1990, *Lightning protection of structures – Part 1: General principles*

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

IEC 61312-3, *Protection against lightning electromagnetic impulse – Part 3: Requirements of surge protective devices**

IEC 61312-4, *Protection against lightning electromagnetic impulse – Part 4: Protection of equipment in existing structures*

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* To be published.

1.3 Terms and definitions

For the purposes of this technical specification, the following terms and definitions apply, as well as those already defined in IEC 61312-1 and IEC 61024-1.

1.3.1
EMC
electromagnetic compatibility

1.3.2
gridlike spatial shield
magnetic shield for a building or a room preferably built by crossed rods of natural components of the structure (e.g. rods of reinforcement in concrete, metal frames and metal supports). This kind of shield is characterized by openings

1.3.3
immunity against damage
withstand capability against conducted and radiated lightning effects

1.3.4
LEMP
lightning electromagnetic impulse

1.3.5
LPS
lightning protection system, as defined in IEC 61024-1

1.3.6
LPZ
lightning protection zone

1.3.7
SPD
surge protection device

1.4 Symbols

1.4.1	b	width (lateral length)
1.4.2	d_r	shortest distance between the point considered and the roof of the shield of LPZ 1
1.4.3	d_w	shortest distance between the point considered and the wall of the shield of LPZ 1
1.4.4	$d_{l/w}$	distance of a loop from the wall
1.4.5	$d_{l/r}$	average distance of a loop from the roof
1.4.6	d_s	safety distance from the shield (against unacceptable high magnetic fields)
1.4.7	$d_{s/1}$	safety distance in case of nearby lightning strike
1.4.8	$d_{s/2}$	safety distance in case of direct lightning strike
1.4.9	H_f	magnetic field of the first stroke
1.4.10	H_n	magnetic field in LPZ n
1.4.11	H_0	magnetic field in LPZ 0_A and LPZ 0_B
1.4.12	H_s	magnetic field of the subsequent strokes
1.4.13	i_f	lightning current of the first stroke in LPZ 0_A

1.4.14 i_i partial lightning current

1.4.15 i_n conducted current in LPZ *n*

1.4.16 i_0 lightning current in LPZ 0_A

1.4.17 i_s lightning current of the subsequent strokes in LPZ 0_A

1.4.18 i_{sc} short-circuit current

1.4.19 k_H configuration factor

1.4.20 l length

1.4.21 L self-inductance of a loop

1.4.22 M mutual inductance of an (induction) loop

1.4.23 *max* index for maximum value

1.4.24 r radius

1.4.25 s_a average distance between the point of strike and the shield

1.4.26 *SF* shielding factor, attenuation value of a shield

1.4.27 T_1 front time of the lightning current, as defined in IEC 61312-1

1.4.28 $T_{p/f}$ time to the maximum value of the first stroke

1.4.29 $T_{p/s}$ time to the maximum value of the subsequent strokes

1.4.30 u_n conducted voltage in LPZ *n*

1.4.31 u_{oc} open-circuit voltage

1.4.32 w mesh width of a gridlike shield

1.4.33 V_s safe volume inside a gridlike shield

2 Electromagnetic source and victim of interference

Figure 1 gives an example of an actual electromagnetic compatibility (EMC) situation, showing a structure with the lightning protection zones LPZ 0, LPZ 1 and LPZ 2. The information (electronic) equipment is installed inside LPZ 2.

The primary electromagnetic source of interference to the information equipment is the lightning current i_0 and the magnetic field H_0. Along incoming services flow partial lightning currents i_i. The currents i_0 and i_i as well as the magnetic field H_0 have the same waveshape. According to IEC 61312-1, clause 2, the lightning current to be considered here consists of a first stroke i_f (10/350 µs) and subsequent strokes i_s (0,25/100 µs). The current of the first stroke i_f generates the magnetic field H_f, and the current of the subsequent strokes i_s generates the magnetic field H_s.

The magnetic induction effects are mainly determined by the rise of the magnetic field to the maximum value. As shown in figure 2 the rise period of H_f can be characterized by a damped oscillating field of 25 kHz with the maximum value $H_{f/max}$ and the time to the maximum value $T_{p/f}$ of 10 µs. In the same way the rise period of H_s can be characterized by a damped oscillating field of 1 MHz with the maximum value $H_{s/max}$ and the time to the maximum value $T_{p/s}$ of 0,25 µs.

From this it follows that with respect to the magnetic induction effects, the magnetic field of the first stroke can be characterized by a typical frequency of 25 kHz and the magnetic field of the subsequent strokes can be characterized by a typical frequency of 1 MHz. Damped oscillating magnetic fields of these frequencies are defined for test purposes in IEC 61000-4-9 and IEC 61000-4-10.

The victim of interference is the information equipment with an inherent immunity against damage caused by conducted and radiated lightning effects.

By installing lightning protection zones (LPZ) with electromagnetic shields and surge protective devices (SPD) at the interfaces of the LPZs, the original lightning effect defined by H_0, i_0 and i_i is reduced to the resistibility level of the victim. As shown in figure 1, the victim shall withstand the surrounding magnetic field H_2 and the conducted lightning effects u_2, i_2 respectively.

The reduction of i_1 to i_2 and the resulting u_2 are the subject of IEC 61312-3. The reduction of H_0 to a sufficient low value of H_2 is the subject of this technical specification.

In case of gridlike spatial shields considered here, it can be assumed that the shape of the magnetic field inside the LPZs (H_1, H_2) is the same as the shape of the magnetic field outside (H_0).

With respect to protection of information equipment against LEMP, it is desirable that the equipment's immunity against damage be proven by appropriate tests according to IEC 61000-4-5 (conducted overvoltages and currents), IEC 61000-4-9 (radiated magnetic field caused by the first stroke) and IEC 61000-4-10 (radiated magnetic field caused by the subsequent strokes).

In figure 2 it is shown that the tests defined in IEC 61000-4-9 and IEC 61000-4-10 simulate, in a sufficient way, the rise of the magnetic field of the first stroke H_f and of the subsequent strokes H_s.

NOTE 1 The tests defined in IEC 61000-4-5, IEC 61000-4-9 and IEC 61000-4-10 are used to prove the immunity of an equipment. Out of the four immunity levels defined, only the immunity level against damage is considered in this technical specification.

NOTE 2 If the buildings or rooms containing the information equipment are sufficiently shielded against the magnetic field by large volume shields, normally this measure will reduce the transient electric field to a sufficiently low value.

3 Gridlike spatial shields

In practice, large volume shields of structures or rooms are built by natural components such as metal supports, metal frames or metal reinforcement rods. These components build up a gridlike large volume shield. The conducting elements penetrating a shield shall be bonded to the shield as close as possible.

Figure 3 shows, in principle, how metal reinforcement in concrete and metal frames (for metal doors and possibly shielded windows) can be built to a large volume shield for a building or a room.

If an individual experimental or theoretical investigation of the shielding effectiveness is not done, the attenuation shall be evaluated as follows.

3.1 Gridlike spatial shields in the case of nearby lightning strikes

The situation in the case of a nearby lightning strike is shown in figure 4. The incident magnetic field at the shielded volume can be approximated as a plane wave.

The incident magnetic field H_0 of LPZ 0 shall be calculated as:

$$H_0 = i_0/(2 \cdot \pi \cdot s_a) \quad \text{(A/m)}$$

where

i_0 is the lightning current in amperes

s_a is the average distance in meters between the point of strike and the shielded volume considered (see figure 4)

From this follows

– for the maximum value of the magnetic field caused by the first stroke

$$H_{0/f/max} = i_{f/max}/(2 \cdot \pi \cdot s_a) \quad (A/m)$$

– and for the maximum value of the magnetic field caused by the subsequent strokes

$$H_{0/s/max} = i_{s/max}/(2 \cdot \pi \cdot s_a) \quad (A/m)$$

where

$i_{f/max}$ is the maximum value of the current of the first stroke, chosen according to the protection level, in amperes

$i_{s/max}$ is the maximum value of the current of the subsequent strokes, chosen according to the protection level, in amperes

The reduction of H_0 to H_1 inside LPZ 1 can be derived from the formulae for the *SF*-values given in table 1, although table 1 is normally only valid for a plane field. The values taken from the formulae of table 1 are valid for a safety volume V_s inside LPZ 1 with a safety distance $d_{s/1}$ from the shield (see figure 5):

$$d_{s/1} = w \cdot SF/10 \quad (m)$$

where

SF is the shielding factor evaluated from the formulae of table 1, in decibels;

w is the mesh width of the gridlike shield, in meters.

From the *SF*-values the magnetic field inside LPZ 1, H_1, can be calculated

$$H_1 = H_0/10^{SF/20} \quad (A/m)$$

where

SF is the shielding factor evaluated from the formulae of table 1, in decibels

H_0 is the magnetic field of LPZ 0, in amperes per meter, identical to $H_{0/f/max}$, $H_{0/s/max}$ respectively

3.2 Gridlike spatial shields in the case of direct lightning strikes

For the purpose of lightning protection, the shield of a building (shield surrounding the LPZ 1) can be a part of LPS, and therefore lightning currents may flow along it. For this kind of shield, characteristics for the magnetic field inside are not yet defined.

The gridlike spatial shields are built up in practice by, for example, steel frames, metal supports and metal reinforcement. These shields may surround LPZ 1.

The lightning flash may hit the structure at an arbitrary point of the roof.

For the magnetic field strength H_1 at an arbitrary point inside volume V_s of LPZ 1, caused by the first stroke, the following formula applies:

$$H_1 = k_H \cdot i_0 \cdot w/\left(d_w \cdot \sqrt{d_r}\right) \quad (A/m)$$

From this it follows that for the magnetic field strength at an arbitrary point inside volume V_s of LPZ 1, caused by the first stroke:

$$H_{1/f/max} = k_H \cdot i_{f/max} \cdot w/\left(d_w \cdot \sqrt{d_r}\right) \quad \text{(A/m)}$$

and for the magnetic field at an arbitrary point inside LPZ 1, caused by the subsequent strokes:

$$H_{1/s/max} = k_H \cdot i_{s/max} \cdot w/\left(d_w \cdot \sqrt{d_r}\right) \quad \text{(A/m)}$$

where

d_r is the shortest distance, in meters, between the point considered and the roof of the shield of LPZ 1

d_w is the shortest distance, in meters, between the point considered and the wall of the shield of LPZ 1

$i_{f/max}$ is the maximum value of the current of the first stroke, in amperes, chosen according to the protection level

$i_{s/max}$ is the maximum value of the current of the subsequent strokes, in amperes, chosen according to the protection level

k_H is the configuration factor $\left(1/\sqrt{m}\right)$. $k_H = 0{,}01$ $\left(1/\sqrt{m}\right)$

w is the mesh width, in meters, of the gridlike shield of LPZ 1

The values of the magnetic field are valid for volumes V_s inside the gridlike shields defined by a safety distance $d_{s/2}$ (see figure 5):

$$d_{s/2} = w \quad \text{(m)}$$

(Electronic) information equipment shall only be installed inside the volumes V_s. Thus the extremely high field values in the immediate vicinity of the grids shall not be considered as source of interference for the information equipment.

For additional information about the calculation of the magnetic field strength see annex C.

3.3 Gridlike spatial shields surrounding LPZ ≥ 2

In the gridlike shields surrounding LPZ 2 and further LPZ, no essential partial lightning currents will flow. Therefore in a first approach the reduction of H_n inside LPZ n to H_{n+1} inside LPZ n+1 can be evaluated from the formulae for the *SF*-values given in table 1 although table 1 is valid for a plane field ($n \geq 1$).

The values taken from the formulae of table 1 are valid for a volume inside LPZ n+1 with a safety distance $d_{s/1}$ from the shield:

$$d_{s/1} = w \cdot SF/10 \quad \text{(m)}$$

where

SF is the shielding factor evaluated from the formulae of table 1 in decibels

w is the mesh width of the gridlike shield in metres