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CONSIDERATIONS ON EFFICIENCY FOR INTERNAL LIGHTNING PROTECTION

An ordinary life area has numerous structures, systems, buildings, objects and components that are susceptible to lightning strikes. The effects of strikes can include actuation of safety systems, and loss of living areas. Protection of critical structures and applying necessary protection measures should be determined in terms of risk, completely risk management. The paper deals with results of investigation on efficiency of internal protection. The attention has been paid to the efficiency of the shields and to their kinds, arrangement, equipotential bonding and grounding according to the concept of lightning protection zones (LPZ).

Keywords: internal lightning protection, surge protection devices, risk management.

1. Introduction

As it can be observed the present-day structures are progressively equipped with electrical and electronic devices, which – due to their sensitivity to lightning electromagnetic impulses – need to be protected with increasing level of efficiency, so a new task for lightning protection measures appears and should be considered with great attention. External LPS [1] is usually not sufficient and special protection measures as additional shields or screens, wiring routing, equipotential bonding, surge protection devices (SPDs), and so on, have to be adopted [2], [3].

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The protection of electrical and electronic systems in buildings and structures against surges resulting from the lightning electromagnetic pulse (LEMP) is based on the principle of Lightning Protection Zones (LPZ) [4]. The efficiency of protection against LEMP depends not only on the kind of a measure applied but also on the way of its performance [5]. To reach an optimal protection, one should follow the concept of lightning protective zones (LPZs), according to which the hazard for sensitive equipment decreases with increasing number of a zone. Lightning interception points create the boundary between the external zones LPZ 0_A, LPZ 0_B and the first internal one LPZ 1 (Fig. 1). Inside LPZ 1 an additional zone (LPZ 2) or more, if needed, may be selected. The shield or screen around LPZ 1 is commonly obtained by means of interconnected conductors, which as natural elements are distributed along the walls, roof and foundations of a structure or as special elements are integrated into the LPS cage. Screens positioned around the successive internal zones may have similar spatial construction and should be interconnected and bonded with the LPS cage.

Incoming lines should be also bonded with LPS and screens by means of SPD and bonding bars. Entire arrangement as considered in Fig. 1 should be well grounded. In this way the protection of electrical and electronic equipment against direct LEMP and its influence by means of incoming lines will be obtained. There is only a problem of efficiency of such protection. Lightning electromagnetic fields penetrating every successive zone should be reduced at zone boundaries by their grid like spatial screens but there is no simple relation between efficiencies for single and combined shields and it needs to be investigated.

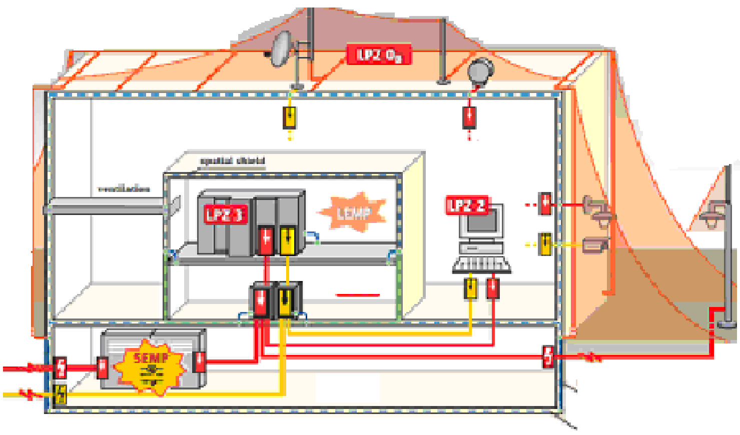

Fig. 1. Lightning protection zones concept according to IEC 62305–4

2. LEMP protection management

A shield or screen may be natural one, consisting of constructive parts of a structure (its walls, roof and foundations) or may be installed together with the structure(s) against LEMP. For new buildings and structures, optimum protection of electronic systems can only be achieved with a minimum of expense if the electronic systems are designed together with the building and before its construction. In this way, building components such as the reinforcement, the metal bars and metal supports can be integrated into the LEMP protection management.

For existing buildings and structures, the cost of the LEMP protection is usually higher than for new buildings and structures. If, however, the LPZs are chosen appropriately and existing installations are used or upgraded, the costs can be reduced.

The risk analysis for LEMP protection is required in accordance with IEC 62305–2. This can only be achieved with the measures taken by lightning protection expert, and he/she must be in close coordination with other engineers.

3. Calculation of the magnetic shield reduction at building shielding

Lightning current and the associated electromagnetic field represent the primary source of interference for devices and installations requiring protection in a property. Figure 2 shows the principle of how lattice structures work.

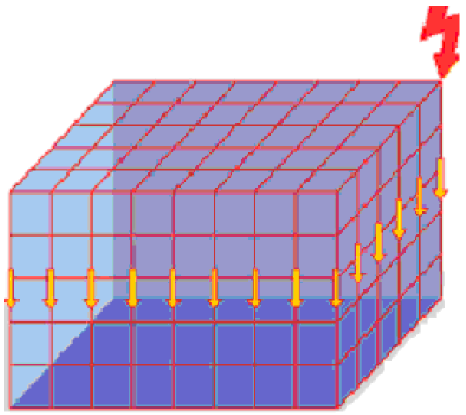

Fig. 2. Reduction of the magnetic field by means of lattice shields

In the case, in which the conductive elements of a structure construction don't exist or are not sufficient in order to shield the LEMP-sensitive equipment, the structure should be equipped with a special shielding arrangement as shown in Fig. 1. Usually, it may be an external LPS cage with increased density of air termination conductors and down conductors, but in special cases a multiple cage should be taken in account. Screening cages, both natural and specially built, have to assure their efficiency compatible with immunity of the equipment.

The shielding effect of lattice-shaped shields in the event of direct lightning strikes is shown in Figure 3, and magnetic field caused by direct lightning strike can be calculated using the formula shown in Eq.1.

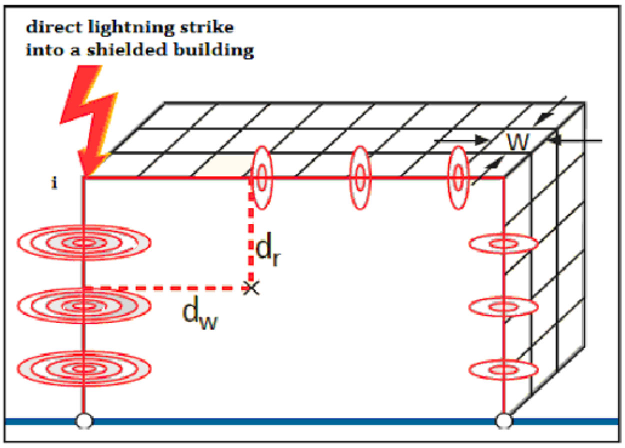

Fig. 3. Magnetic field at a lightning strike

$$H_1 = k_h \cdot i_0 \cdot \frac{w}{d_w \cdot \sqrt{d_r}} \text{ (A/m)} \quad (1)$$

where: i_0 is lightning current in LPZ 0_A, H_1 is magnetic field density, and k_h is written as (kV/A√m).

Fig. 3 is based on the fact that the lightning strike can happen at any point on the roof. The values calculated for the magnetic field apply to the safety volume V_S inside lattice-shaped shields, which are defined by the separation distance $d_{s/1}=w$. This is shown in Fig.4.

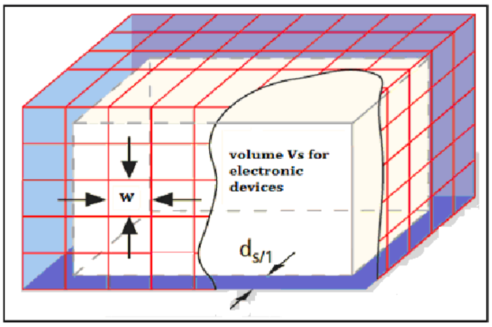

Fig. 4. Volume for electronic devices within LPZ 1

As shown in Fig. 4, the safety volume takes into account maximum values of the magnetic field strength directly at the lattice structure, a factor which the approximation formula does not sufficiently take into account. IT devices may only be installed inside of volume V_s.

4. Calculation of strike effects in lattice-shaped shields

There is no different approach to the evaluation of screening efficiency of natural screens and of the screens especially installed. In both cases the calculation procedure cannot be very exact and allows obtaining only approximated results. According to this procedure the screening factor S may be defined in relative values as given in Eq. 2.

$$S = \frac{H_0}{H} \tag{2}$$

or in decibels as a screening efficiency as given in Eq. 3.

$$S_{\mathrm{dB}} = 20\log\frac{H_0 A}{H} \tag{3}$$

Sometime it is reasonable to apply converse factor as a field reduction factor as given in Eq. 4.

$$K = \frac{1}{S} = \frac{H}{H_0} \tag{4}$$

where: H_0 – field without screen; H – field inside the screen in the same place as H_0 in relation to the lightning channel.

From theoretical point of view the resulting screening efficiency S_{dB} (in decibels) is the sum of efficiencies of individual screens as following factor as given in Eq. 5.

$$S_{db} = S_{1db} + S_{2db} \tag{5}$$

The values of S_{dB}, S_{1dB}, S_{2dB} depend on the reciprocal position of the structure and the channel of lightning strike. The value of S_{dB} shows the sum of the individual screens.

Figure 5 shows the principle how a steel reinforcement can be developed into an electromagnetic cage (hole shield).

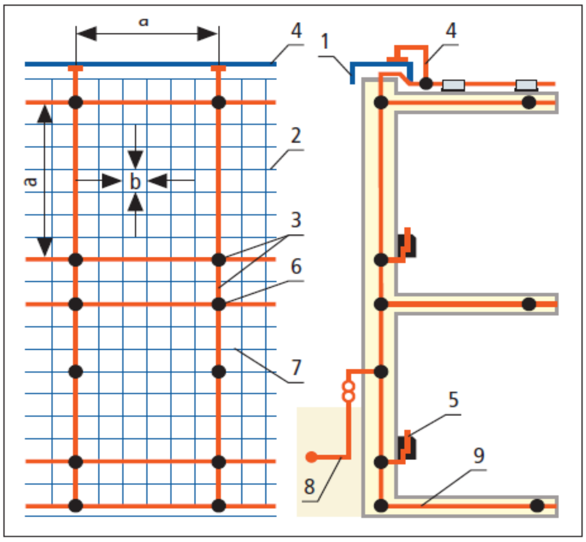

Fig. 5. Reinforcing rods at shielding

The marked terms are given as 1–metal cover, 2–steel rods, 3–intermeshed conductors, 4–connection of the air termination system, 5–internal equipotential bonding bar, 6–connection capable of carrying lightning currents, 7–connection, 8–ring earth electrode, 9–foundation earth electrode.

This meshed network is connected at the crosspoints, by means of clamps. As seen from Fig.5, the dimensions a ≤ 5 *m* and b ≤ 1 *m*.

Two cases of lightning strike have been taken into considerations as nearby strike, and direct strike. In the second case the strikes into the upper corner of the structure and into its centre are taken in account.

Nearby strikes

In the case of nearby strike, the calculation of the shielding effect of lattice-shaped shields for nearby lightning strikes is explained more in detail by Figure 6. The formation of the electromagnetic field whose reduction in field strength is indirectly proportional to the distance S_a magnitude of the magnetic field inside a protected volume, e.g. lightning protection zone LPZ 1 can be described by the quality of the shielding.

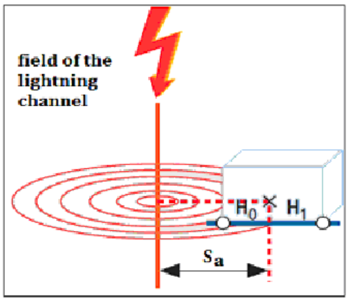

Fig. 6. Magnetic field at a distance lightning strike (IEC 62305–4)

The magnetic field at this distance may be assumed to be uniform and equal as given in Eq. (6)–(7) without and with shield.

$$H_0 = \frac{i}{2 \cdot \pi \cdot S_a} \tag{6}$$

$$H_1 = \frac{H_0}{10^{SF_1/20}} \tag{7}$$

where: i – maximum value of lightning current, and SF – the shielding factor.

The shielding factor can be calculated from the tables according to IEC 62305–4. However the distribution of this field in the structure will be changed by its natural metallic elements or by a specially installed grid like screen. It is due to coupling of the elements with lightning channel and due to induced currents in these elements. As a result the values of magnetic field in different points of the structure may be much less than H_0 but also the case of field amplification is not excluded. Every side of the cage has been equipped with additional conductors uniformly distributed between edges.

Direct strikes

The situation becomes complicated, when the cage is struck by lightning and its current is distributed between several conductors. It is very difficult to define the screening efficiency S_{dB} because for the case without the cage the magnetic field and its effects are quite virtual. There is no distribution of the lightning magnetic field without the cage.

To avoid the difficulty connected with the definition of screening efficiency it was assumed that lightning channel has been prolonged vertically from the interception point to the earth surface as if the cage was not conductive one or simply not present one. It means that in the case of lightning strike into the interception point of such "not conducting cage" the channel should be located in the vertical line passing through this point.

Proposed evaluation

An observation of results obtained from performed investigations and calculations allows to state that there is a certain relation between the number of conductors in shielding cages and shielding efficiency. On the back ground of this observation it is possible to express the shielding efficiency in terms of distance *w* between down conductors of shielding cages.

5. Conclusions

The efficiency of the screens should be coordinated with the immunity of structure equipment. Investigations and considerations on efficiency of the screens applied for protection of sensitive equipment against LEMP allow to formulate the following conclusions:

- the screens used for protection structure equipment against influence of lightning magnetic field should be selected and installed according to the LPZ concept;
- internal shields at the boundary between LPZ 1 and LPZ 2 should be applied, when the efficiency of external screens are not sufficient;
- the efficiency of internal screen is less than that of external one with similar construction;
- values of screening efficiency depend on the conductor number in complicated way but there is a possibility to formulate its general approximation;
- investigations on shielding efficiency should be continued.

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ROZWAŻANIA NA TEMAT EFEKTYWNOŚCI WEWNĘTRZNEJ OCHRONY ODGROMOWEJ

S t r e s z c z e n i e

Na obszarze zabudowanym znajdują się różne budynki i inne obiekty, które mogą być narażone na wyładowania atmosferyczne. Efektem tych wyładowań może być uruchomienie systemów zabezpieczeń oraz straty na obszarach zamieszkałych. Ochrona ważnych obiektów i zastosowanie środków ochrony powinno być określone w odniesieniu do wyznaczonego ryzyka. W artykule przedstawiono wyniki badań związanych z efektywnością wewnętrznej ochrony. Uwagę zwrócono na efektywność ekranów i ich rodzaje, wyrównywanie potencjałów i uziemienie zgodne z koncepcją strefowej ochrony odgromowej.

Słowa kluczowe: wewnętrzna ochrona odgromowa, ograniczniki przepięć, zarządzanie ryzykiem

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