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Essential Recommendations of Electromagnetic Compatibility for Office Buildings

Abstract: *Essential recommendations of electromagnetic compatibility (EMC) for electrical installations in office buildings are briefly summarized. Measures of protection against electromagnetic disturbances are discussed. They are: a lightning protection system, grounding, bonding, overvoltage arresters, cable routing, safe distances, shielding.*

Streszczenie. *Zwięźle przedstawiono główne zalecenia dotyczące kompatybilności elektromagnetycznej dla instalacji elektrycznych w budynkach biurowych. Przedyskutowano środki ochrony przeciw zaburzeniom elektromagnetycznym. Są to: instalacja odgromowa, uziemianie, wyrównywanie potencjałów, ograniczniki przepięć, dobór tras kabli, odstępy bezpieczne, ekranowanie. (**Zasadnicze zalecenia dotyczące kompatybilności elektromagnetycznej w budynkach biurowych**).*

Keywords: electromagnetic compatibility, lightning protection, overvoltage, office building.
Słowa kluczowe: kompatybilność elektromagnetyczna, ochrona odgromowa, przepięcia, budynek biurowy.

Introduction

Protection against electromagnetic disturbances (EMD) in office buildings is carried out using:

- air terminations and downconductors of a lightning protection system (LPS),
- grounding,
- bonding (equipotentialization),
- surge protection devices (SPDs) and filters,
- cable routing,
- safe distances,
- shielding.

Understanding of causes of EMD, consciousness of risk, and knowledge of protection measures are still relatively small. Only selected essential recommendations are summarized in this paper due to the volume limitations.

A properly designed protection system is effective against any kind of typical disturbances, including lightning electromagnetic pulse (LEMP) [1, 2, 3].

Essential rule of protection

The essential rule of protection against EMD is to identify a protected volume (zone) and to mount the protective devices onto its boundary (not outside or inside the protected volume). Typically, the boundary is easy to determine: walls of a building, of a room, or a device box.

Air terminations and downconductors

It is crucial to observe requirements of the IEC/EN lightning protection standards [3] during a design process of an efficient LPS. The efficiency may be interpreted as the probability of evading damages in the case of direct lightning strike onto the protected object.

A lot of misunderstandings concern the identification of a zone protected by the LPS in the neighborhood of tall objects of height h (e.g. an antenna tower, a factory stack). The easiest way is to determine the protected zone as a volume below a rolling sphere of radius R [3]. Note that in the case of $h > R$ the protected zone does not depend on h.

A commonly met misconception is met where protected devices (e.g. antennas, air vents, chillers of an air condition system) are the highest parts of buildings. They should be protected by vertical lightning rods or by horizontal air terminations so as not to protrude above the LPS. Safe distances between the protected devices and the LPS should be observed. The protected devices should not be bonded to the LPS (often met error) so as not to let the part of lightning current flow into the electric circuits.

Non-standard lightning protection

A lot of non-standard lightning protection devices are met on the market. They are classified into two groups: *early streamer emitters* (ESE) and *lightning preventors* (*eliminators*). Making use of these devices is not recommended. Neither data nor theory supports claims that "lightning elimination" and "early streamer emission" techniques are superior to conventional lightning protection systems [4]. These devices can cause additional electromagnetic threats, including even life hazard.

Grounding system

To avoid damages the energy of disturbances should be transferred to the ground via dedicated conducting paths (PE conductors). These paths should be as short as possible to reduce unwanted voltage drops and to minimize the electromagnetic coupling to protected circuits.

A typical grounding system is made of galvanized steel. It is recommended to make use of reinforcement for grounding of new buildings. The steel in concrete is much more corrosion-resistant than in the soil. The resistance to the earth of the reinforcement grounding system is less dependent on the seasonal changes of temperature and water content than that of the perimeter grounding electrodes buried directly in the soil.

Different requirements are formulated concerning the resistance to the earth, depending on the function of the grounding system. The grounding system must fulfill the hardest expected requirement. There are misconceptions of so-called "isolated" or "dedicated" grounds (e.g. "protection" ground, "signal" ground, "power" ground, "clean" ground). Note that such ideas can cause many hazards concerning apparatus and even human life. All the protecting and operating functions should be accomplished by a single grounding system [3].

Bonding (equipotentialization)

All metal parts and non-electric installations should be properly bonded – in every place where it is not possible to apply safe distances. The lack of equipotentialization can cause risk of sparking or electric shock during extraordinary circumstances (lightning stroke, short-circuit).

It is important to bond the conducting installations in a basement or at a ground floor, as close to the ground as possible. This concerns water pipelines, sewerage system, central heating pipes, air vents, and fuel system. Gas pipes should be connected to the equipotentialization bars using proper spark gaps (tubes).

To be precise, the "equipotentialization" does not mean that the electrical potentials of all the metal parts in the building are forced to be perfectly equal, but that the potential differences are made safe. Typical surges last for microseconds, so the surge voltage drops along conductors depend mainly on inductances: $u = L\, di/dt$. All the bonding conductors should be as short as possible to minimize their inductances (and potential differences).

One should take care of the quality of electric contacts. The quality strongly depends on the choice of contacting metals. The choice of metals should be done with care because of corrosion. The commonly met error is that contacting metals are of different electrochemical potentials, e.g. copper and galvanized steel, aluminum and copper, aluminum and steel. Such contacts form galvanic corrosion cells. The *Cu-Fe*, *Al-Cu* or *Al-Fe* contacts can be made corrosion-resistant if proper metal interleaf is applied, e.g. tin, brass [5].

Making use of grounded copper bars mounted along the walls of technical rooms is recommended for the purpose of equipotentialization. It is easy to connect the apparatus PE clenches with the copper bar using short wires or straps. Such connections assure very good quality and they are easy for inspection.

In many apparatus rooms a one-point or so-called "star" scheme of PE cables is seen. Strange, how often this scheme is still applied, though it was applicable fifty years ago (within the kilohertz frequency band of analogue devices) and is not suitable for present-day wideband digital electronic systems. While working in the wide frequency spectrum the unwanted resonant effects can occur, if the PE cable length is comparable to $\lambda/4 + k\,\lambda/2$ (where λ denotes the wave length and $k = 0, 1, 2, ...$).

The best solution for equipotentialization in apparatus rooms is to apply the equipotentialization grid below the technical elevated floor. Such grid provides many paths for distribution of wideband interference currents, making it possible to attenuate multiple resonances. The PE clenches should be connected to this grid using the shortest possible wires or straps. One should connect the equipotentialization grid with the grounding system in several places, applying irregular distances, and using wires of different lengths to minimize resonant effects.

Cable routing, safe distances

One can often see cables touching the LPS system or erroneously tied to the LPS conductors. If lightning strikes the building then a part of its energy will penetrate interior installations through such conducting paths.

Safe distances *s* should be assured between the LPS conductors and electrical circuits. The safe distances increase with the increase of the height above the ground (or above the equipotentialization platform). Formulas for determination of safe distances are given in [3]. For a not very tall building (of few floors) a rough estimation of *s* can be applied: $s \approx h/10$, where *h* stands for the building height.

Safe distances from the LPS should be observed both outside and inside buildings. One should not route cables or place electronic apparatus close to a wall if an LPS downconductor is fixed to another side of this wall.

Cable routes should be planned in such a way as to minimize loops formed by cable shields and PE conductors. Typical issues concerning currents induced in cable shields are involved with errors in cable routing and disregarding the phenomenon of electromagnetic induction in loops.

Cables of different functions should be grouped, and cable groups should be separated, For example, power cables and signal cables should not be neither bundled nor placed in the same cable tray (one of often met errors is placing different cables in the same tray).

Shielding

An electromagnetic (EM) shield is a conductive barrier intended for reduction of EM field inside or outside shielded volume. Every shield is a part of an equipotentialization system and conducts exclusively interference currents. A shield, as well as a bonding wire, does not conduct working currents. One must not let the working current flow through shielding conductors. Due to this interpretation, one may not consider an outer conductor of a coaxial cable as a shield. Understanding of this fact is crucial for proper cable shielding and bonding techniques.

It is noteworthy that in many cases properly connected reinforcement bars and/or LPS conductors [3, 6, 7] can serve as an efficient grid-like shield.

Surge protection devices

SPDs (or overvoltage arresters) are popular at the market from about 20 years. Many data can be found in trade periodicals and manufacturers' catalogues.

SPDs combining characteristics two or three levels of protection (I+II, II+III, I+II+III), or classes of protection (B+C, C+D, B+C+D) in power supply lines have been developed from several years. They can be applied in AC circuits of small or medium office buildings.

Input and output of the SPD circuits should be geometrically located at the opposite sides, so as to minimize the electromagnetic coupling between protected and non-protected cables. Wires connecting the SPDs should be as short as possible to minimize the inductive voltage drops $u = L\, di/dt$.

SPDs in the AC power lines are already standardized. The present stage of development of overvoltage arresters in signal circuits is much more complex. Typically only vital ports are equipped with SPDs because of high cost of protection of every signal line in a multiport system.

The often met error is the lack of connection between an SPD and an equipotentialization bar. As a result the surge energy has no conductive path to the ground, and the SPD can be damaged itself.

Conclusion

The essential issues concerning EMC in office buildings have been pointed out. Protection against all kinds of electromagnetic disturbances should be treated in an integral manner because the protection measures complement each other.

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