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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 5-3: Installation and mitigation guidelines – HEMP protection concepts

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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Technical reports do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful by the maintenance team.

IEC 61000-5-3, which is a technical report, has been prepared by subcommittee 77C: Immunity to high altitude nuclear electromagnetic pulse (HEMP), of IEC technical committee 77: Electromagnetic compatibility.

It has the status of a basic EMC publication in accordance with IEC Guide 107.

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

Enquiry draft	Report on voting
77C/58/CDV	77C/69/RVC

Full information on the voting for the approval of this technical report 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.

This document, which is purely informative is not to be regarded as an International Standard.

INTRODUCTION

IEC 61000-5 is a part of the IEC 61000 series, according to the following structure:

Part 1: General

General considerations (introduction, fundamental principles)

Definitions, terminology

Part 2: Environment

Description of the environment

Classification of the environment

Compatibility levels

Part 3: Limits

Emission limits

Immunity limits (in so far as these limits do not fall under the responsibility of the product committees)

Part 4: Testing and measurement techniques

Measurement techniques

Testing techniques

Part 5: Installation and mitigation guidelines

Installation guidelines

Mitigation methods and devices

Part 6: Generic standards

Part 9: Miscellaneous

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 5-3: Installation and mitigation guidelines – HEMP protection concepts

1 Scope

This part of IEC 61000 defines and gives information on protection concepts against electromagnetic pulse due to a high altitude nuclear explosion (denoted in what follows by the abbreviation HEMP).

The aim of this technical report is to provide elements for

– the design of an adequate protection for civil facilities against HEMP;
– the evaluation of already existing protections with respect to stresses imposed by HEMP;
– the comparison of the requirements of HEMP and lightning protection in order to show if they can be combined at low cost;
– an emphasis of the differences between the requirements of HEMP and lightning protection in order to permit an evaluation of the consequences of HEMP when no additional measures are taken beyond existing lightning protection.

2 Reference documents

IEC 60050(161):1990, *International Electrotechnical Vocabulary (IEV) – Chapter 161: Electromagnetic compatibility*

IEC 60060-2:1994, *High voltage test techniques – Part 2: Measuring systems*

IEC 60099-1:1991, *Surge arresters – Part 1: Non-linear resistor type gapped arresters for a.c. systems*

IEC 61000-2-9:1996, *Electromagnetic compatibility (EMC) – Part 2: Environment – Section 9: Description of HEMP environment – Radiated disturbance.* Basic EMC publication

IEC 61000-2-10:1998, *Electromagnetic compatibility (EMC) – Part 2-10: Environment – Description of HEMP environment – Conducted disturbance.* Basic EMC publication

IEC 61000-2-11, *Electromagnetic compatibility (EMC) – Part 2-11: Environment – Description of HEMP environment – Classification of HEMP environments* [1)]

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

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1) To be published.

IEC 61000-4-23, *Electromagnetic compatibility (EMC) – Part 4-23: Testing and measurement techniques – Test methods for protective devices for HEMP and other radiated disturbance.* Basic EMC publication [1]

IEC 61000-4-24:1997, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 24: Test methods for protective devices for HEMP conducted disturbances.* Basic EMC publication.

IEC 61000-4-25, *Electromagnetic compatibility (EMC) – Part 4-25: Testing and measurement techniques – HEMP requirements and test methods for equipment and systems.* Basic EMC Publication [1]

IEC/TR 61000-5-4:1996, *Electromagnetic compatibility (EMC) – Part 5: Installation and mitigation guidelines – Section 4: Immunity to HEMP – Specification for protective devices against HEMP radiated disturbance.* Basic EMC Publication

IEC 61000-5-5:1996, *Electromagnetic compatibility (EMC) – Part 5: Installation and mitigation guidelines – Section 5: Specification of protective devices for HEMP conducted disturbance.* Basic EMC Publication

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

3 Definitions

For the purpose of this technical report, the definitions of IEC 60050(161) together with the following definitions apply.

3.1
electromagnetic barrier
topologically closed surface made to prevent or limit EM fields and conducted transients from entering the enclosed space. The barrier consists of the shield surface and points-of-entry treatments and encloses the protected volume

3.2
penetration
transfer of electromagnetic energy through an electromagnetic barrier from one volume to another. This can take place in different ways: by diffusion through the barrier, through apertures and through conductors connecting the two volumes (wires, cables, conduits, pipes, ducts, etc.)

4 General

The subject of HEMP is covered from an environmental point of view in clause 3 of IEC 61000-2-9 and IEC 61000-2-10.

The discussion of the protection concepts refers to shielding procedures for buildings, equipments and connections between them (transmission lines and cables). The term "shielding" is used here in its more general sense, i.e. cages, cabinets, shielded cables, filtering and surge suppressors.

[1] To be published.

5 Protection principles

5.1 General

This subclause deals with general protection principles that can be applied to most of the protection concepts as defined in clause 7.

In protected areas (buildings, installations, systems or equipment), two main sources of disturbance – direct electromagnetic radiation (radiated disturbance) and conducted penetration of voltage and current surges (conducted disturbance) – are foreseen (see figure 1).

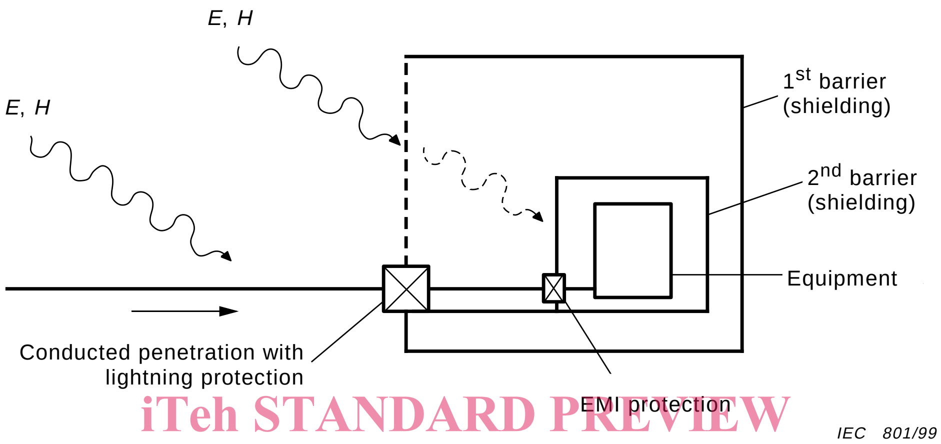


Figure 1 – Example of penetration of radiated and conducted disturbances through a two-barrier protection

This figure shows an example of an installation protected by two barriers. The radiated disturbance may be attenuated by construction elements of buildings (concrete, rebars and other metal parts, etc.) or by metal shields installed specifically for this purpose. Protection against conducted disturbances penetrating via incoming and outgoing lines may be achieved by momentarily short-circuiting the line to the shield, by frequency bandwidth limitation or by combinations of both (e.g. surge protectors plus filters). Very often, such protection already exists in many buildings against lightning. As discussed below, a check shall be performed to decide if the lightning protection complies at least partially with the needs for protection against HEMP. Surge protectors are extremely non-linear elements. Below a certain voltage, their resistance is in the megohm range but during conduction it may be down to less than 1 mΩ. Their effectiveness cannot therefore be expressed in decibels or directly compared to shield effectiveness. The insertion loss of a line filter and the radiation attenuation of a shield also describe two completely different items. Nevertheless, it should be noted that, when the residual voltage (or energy) on a line in the protected area is comparable to the voltage (or energy) that can be induced on the line by fields penetrating the shield, further reduction of the conducted voltage (or energy) will not be very beneficial.

5.2 Zoning

In a spatially extended system, it may be advisable to define zones of different disturbance levels. One reason for this may be that parts of the system are not essential and therefore do not need to be protected, or that some parts of the system are not as susceptible as others. Correct zoning implies that sufficient penetration protection be applied to make the residual conducted disturbance comparable to the radiated disturbance within a zone, so that conducted interference is not a dominant disturbance within the zone. A definition of zoning and a classification of protection zones from an EMC point of view is given in 5.2 of IEC 61000-5-6. This comparison can be performed only by comparing the susceptibility of a given equipment to each kind of disturbance. The susceptibility of the equipment can be determined by specific tests described in IEC 61000-4-25, but the comparison is not straightforward because the equipment can be more or less susceptible to one type of disturbance.

The boundary of a zone is defined by a mechanical structure (concrete building wall, rebar structure or solid metal shield) that has a certain radiation attenuation whose magnitude as a function of the degree of protection is defined in clause 7. Lines penetrating zone boundaries shall be protected against conducted disturbance at every point of entry. If a line penetrates several boundaries, the protective devices shall be coordinated as described in 6.3.3.6. In imperfect shields, i.e. shields with an average attenuation of less than 40 dB from about 14 kHz to 1 GHz (see also IEC 61000-5-4), special care shall be taken that shield currents do not radiate into the zone and do not produce inductive voltage drops between the different points of entry. In such a case, it is advisable to have only one point of entry (single point entry) per zone.

5.3 Protection against radiated disturbance

One function of a shield is to attenuate free-field radiation and to prevent radiation from line currents and shield currents from entering the protected area. This is an important issue for imperfect shields. Mechanical structures such as concrete walls, rebar meshes and metallic structural elements may contribute to the total field attenuation if properly integrated in a multi-shield concept. Optimal use of these structures can only be made if each shield is spatially separated from each other and penetrating lines (and ground connections) enter the shields only at one point per shield. Only by this means can line currents be prevented from flowing into and across protected areas (see figure 1).

5.4 Protection against conducted disturbance

Protective devices shall fulfil two often contradictory requirements. During a surge event (lightning or HEMP) they shall protect the connected equipment either by insulating the longitudinal path or by short-circuiting the transversal path. In the absence of a surge, they should influence the normal operation of the equipment as little as possible. The transition between the two stages should happen within a few nanoseconds or less.

A surge event in a protective device can be described in terms of voltage or current as a function of time. Figure 2 shows an example using a gas arrester. During the first phase, as the voltage rises, the (primary) protection element is still in its insulating state. In this phase, no significant current flows through the device and the event can be treated considering only the breakdown voltage of the dielectric material of the protection element. It is only when the voltage reaches the breakdown or limiting level that a current starts to flow through the protection element and that the thermal process described in terms of action, i.e. proportional to $\int_{t_i}^{t_f} i^2 \mathrm{d}t$, shall be taken into account,

t_i being the initial time of the phenomenon, and

t_f being the final time of the phenomenon.

Prior to choosing protective devices, the following questions shall be answered:

– how often do disturbances (lightning) occur?

– which surge parameters are expected (from lightning and HEMP)?

– what is the maximum residual voltage for each waveform that the equipment connected at the interface can withstand?

– what is the function of the connected equipment or interface?

which parasitic characteristics (longitudinal impedance, insertion loss, capacity, etc.) of the protective device are allowed that do not disturb normal operation ?

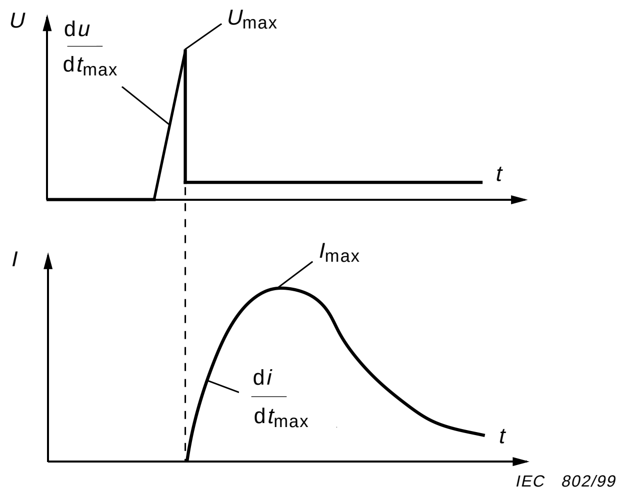


Figure 2 – Voltage and current flowing through a gas arrester during a surge event

As different protective devices may function in different ways, the requirements or specifications for each device type shall be formulated in a manner appropriate to its functioning. For instance, it would not make sense to require a specific firing voltage for a varistor or a minimum energy absorbance for a gas arrester.

5.5 Wiring and installation guidelines

5.5.1 Points of entry

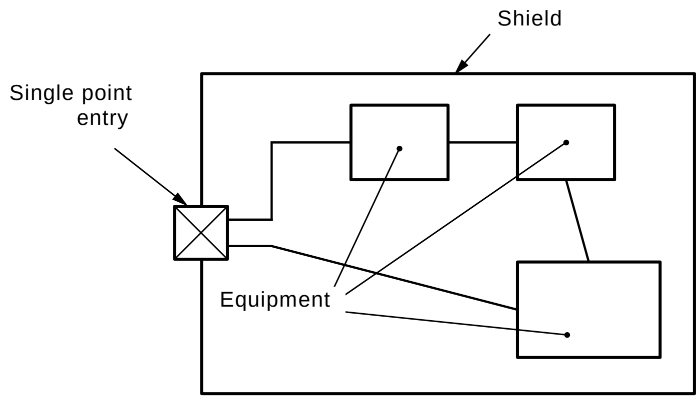
With multiple points of entry into an imperfect shield, inductive voltage drops caused by surge currents flowing on the shield may couple into the protected area and thus by-pass the conducted protective measures. Multiple grounding points inside an imperfect shield increase common mode coupling of the remaining radiation field to the system. It is therefore advantageous to have a single entry point for all cables. This means that all protective measures for penetrating cables should be located on the shield and as close together as possible. This also means that ground potential for all equipment within the protected area should be taken exclusively from the location of the single entry point. In 5.6 it is assumed that only a single point entry and single point grounding are used, and that the equipment housings are insulated from the building (rebars, metallic construction parts, etc.).

5.5.2 Wiring concepts

Two basic concepts for wiring between the point of entry and the internal equipment are shown in figures 3a and 3b.

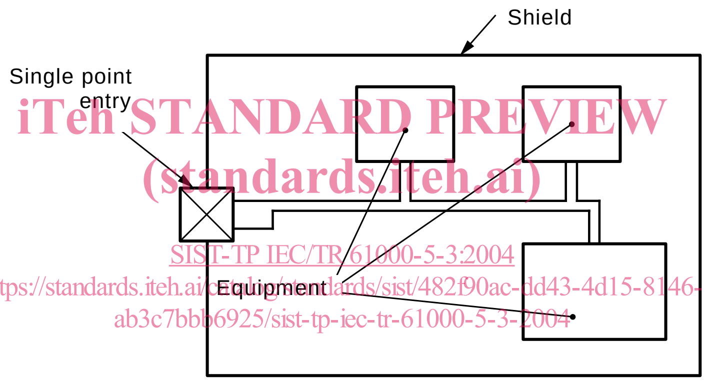
In a mesh-shaped wiring system (see figure 3a), the shield’s internal connections can be installed arbitrarily, permitting induction loops. Penetrating fields induce voltages and currents in wiring loops that may affect the system. Therefore, this concept should only be used with nearly perfect shields where field intensities are low and/or with shielded cables or shielded cable ducts. It should be noted, however, that large loops may lead to mutual interference between equipment in a shielded enclosure.

A tree-shaped wiring system (see figure 3b) contains only loops with a very small area. The penetrating field may induce only common-mode signals to which the system is less susceptible (the signals on the lines and on the system ground are of the same magnitude and phase). This wiring concept is preferably used within low attenuation shields. If high quality shielded cables and/or metal cable ducts are used, the requirement for shield attenuation may be further reduced.



IEC 803/99

Figure 3a - Mesh-shaped wiring system



IEC 804/99

Figure 3b – Tree-shaped wiring system

Figure 3 – Concepts for wiring systems

5.5.3 Cables

If shielded cables or shielded cable ducts are used, the shields shall be interconnected between the sections, whether they are in a tree- or mesh-shaped configuration. The equipment chassis shall also be connected to the shields of the cables. It is highly advisable to implement the concept of shielding continuity, i.e. to use good quality connectors for the entry points of the cables into the equipment and to avoid pigtails which are, in practice, ineffective from an EMC point of view. The pigtails can provide only a protection for persons in case of short circuits of the mains (at power frequency 50 Hz or 60 Hz) to a cable sheath.

5.6 Relation between HEMP and lightning protection principles

From the source point of view, lightning and HEMP are quite different but the radiated and conducted environments produced by the two phenomena are very similar. Thus, HEMP protection principles for civil applications shall take advantage of already installed lightning protection. The designer of the HEMP protection shall estimate if, by admitting a certain risk, the lightning protection can also be considered to be sufficient against HEMP as well. The aim of this subclause is to discuss basic features of the HEMP and lightning environments in order to define a strategy for protecting the equipment.