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INTERNATIONAL STANDARD

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BASIC EMC PUBLICATION

PUBLICATION FONDAMENTALE EN CEM

Electromagnetic compatibility (EMC) –
Part 4-18: Testing and measurement techniques – Damped oscillatory wave immunity test

Compatibilité électromagnétique (CEM) –
Partie 4-18: Techniques d'essai et de mesure – Essai d'immunité à l'onde oscillatoire amortie

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 4-18: Testing and measurement techniques – Damped oscillatory wave immunity test

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of 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, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). 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. 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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This consolidated version of IEC 61000-4-18 consists of the first edition (2006) [documents 77B/517/FDIS and 77B/522/RVD] and its amendment 1 (2010) [documents 77B/604/CDV and 77B/633/RVC]. It bears the edition number 1.1.

The technical content is therefore identical to the base edition and its amendment and has been prepared for user convenience. A vertical line in the margin shows where the base publication has been modified by amendment 1. Additions and deletions are displayed in red, with deletions being struck through.

International Standard IEC 61000-4-18 has been prepared by subcommittee 77B: High frequency phenomena, of IEC technical Committee 77: Electromagnetic compatibility.

It forms Part 4-18 of IEC 61000. It has the status of a basic EMC publication in accordance with IEC Guide 107, *Electromagnetic compatibility – Guide to the drafting of electromagnetic compatibility publications*.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of the base publication and its amendments will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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

IMPORTANT – The "colour inside" logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this publication using a colour printer.

INTRODUCTION

This standard is 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 they do not fall under the responsibility of the product committees)

Part 4: Testing and measurement techniques

Testing techniques

Part 5: Installation and mitigation guidelines

Installation guidelines

Mitigation methods and devices

Part 6: Generic standards

Part 9: Miscellaneous

Each part is further subdivided into several parts, published either as international standards or as technical specifications or technical reports, some of which have already been published as sections. Others will be published with the part number followed by a dash and a second number identifying the subdivision (example: 61000-6-1).

This part is an international standard which gives immunity requirements and test procedures related to damped oscillatory waves.

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 4-18: Testing and measurement techniques – Damped oscillatory wave immunity test

1 Scope and object

This part of IEC 61000-4 relates to the immunity requirements and test methods for electrical and electronic equipment, under operational conditions, with regard to:

a) repetitive damped oscillatory waves occurring mainly in power, control and signal cables installed in high voltage and medium voltage (HV/MV) substations;

b) repetitive damped oscillatory waves occurring mainly in power, control and signal cables installed in gas insulated substations (GIS) and in some cases also air insulated substations (AIS) or in any installation due to HEMP phenomena.

The object of this basic standard is to establish the immunity requirements and a common reference for evaluating in a laboratory the performance of electrical and electronic equipment intended for residential, commercial and industrial applications, as well as of equipment intended for power stations and substations, as applicable.

NOTE As described in IEC guide 107, this is a basic EMC publication for use by product committees of the IEC. As also stated in Guide 107, the IEC product committees are responsible for determining whether this immunity test standard should be applied or not, and if applied, they are responsible for determining the appropriate test levels and performance criteria. TC 77 and its sub-committees are prepared to co-operate with product committees in the evaluation of the value of particular immunity tests for their products.

The purpose of this standard is to define:

– test voltage and current waveforms;
– ranges of test levels;
– test equipment;
– test setup;
– test procedure.

The object of this standard is to establish a common reference for evaluating the immunity of electrical and electronic equipment when subjected to damped oscillatory waves. The test method documented in this part of IEC 61000 describes a consistent method to assess the immunity of an equipment or system against a defined phenomenon.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

IEC 61000-4-4: *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*

IEC 61000-6-6: *Electromagnetic compatibility (EMC) – Part 6-6: Generic standards – HEMP immunity for indoor equipment*

3 Terms and definitions

For the purposes of this document, the terms and definitions contained in IEC 60050-161, some of which are repeated here for convenience, and the following terms and definitions apply.

NOTE These terms are applicable to the restricted field of oscillatory transients.

3.1
air insulated substation
AIS
substation which is made up with only air insulated switchgear

3.2
burst
sequence of a limited number of distinct pulses or an oscillation of limited duration

[IEV 161-02-07]

3.3
calibration
set of operations which establishes, by reference to standards, the relationship which exists under specified conditions, between an indication and a result of a measurement

NOTE 1 This term is based on the "uncertainty" approach.

NOTE 2 The relationship between the indications and the results of measurement can be expressed, in principle, by a calibration diagram.

[IEV 311-01-09]

3.4
coupling
interaction between circuits, transferring energy from one circuit to another

3.5
coupling network
electrical circuit for the purpose of transferring energy from one circuit to another

3.6
decoupling network
electrical circuit for the purpose of preventing test voltages applied to the EUT (equipment under test) from affecting other devices, equipment, or systems which are not under test

3.7
gas insulated (metal-enclosed) substation
GIS
substation which is made up with only gas insulated metal enclosed switchgear

[IEV 605-02-14]

3.8
high-altitude electromagnetic pulse
electromagnetic pulse produced by a nuclear explosion outside the earth's atmosphere

NOTE Typically above an altitude of 30 km

3.9
immunity (to a disturbance)
the ability of a device, equipment, or system to perform without degradation in the presence of an electromagnetic disturbance

[IEV 161-01-20]

3.10
port
particular interface of the EUT with the external electromagnetic environment

3.11
rise time
interval of time between the instants at which the instantaneous value of a pulse first reaches 10 % value and then the 90 % value

[IEV 161-02-05, modified]

3.12
transient (adjective and noun)
pertaining to or designating a phenomenon or a quantity which varies between two consecutive steady states during a time interval short compared with the time-scale of interest

[IEV 161-02-01]

3.13
verification
set of operations which is used to check the test equipment system (e.g. the test generator and the interconnecting cables) and to demonstrate that the test system is functioning within the specifications given in Clause 6

NOTE 1 The methods used for verification may be different from those used for calibration.

NOTE 2 The procedure of 6.1.3 and 6.2 is meant as a guide to insure the correct operation of the test generator, and other items making up the test setup so that the intended waveform is delivered to the EUT.

[IEV 311-01-13, modified]

4 General

The damped oscillatory wave phenomena are divided into two parts. The first part is referred to as the slow damped oscillatory wave and includes oscillation frequencies between 100 kHz and 1 MHz. The second part is referred to as the fast damped oscillatory wave, and it includes oscillation frequencies above 1 MHz. The causes of these two types of damped oscillatory waves are described below.

4.1 Information on the slow damped oscillatory wave phenomenon

This phenomenon is representative of the switching of disconnectors in HV/MV open-air substations, and is particularly related to the switching of HV busbars, as well as to the background disturbance in industrial plants.

In electrical stations, the opening and closing operations of HV disconnectors give rise to sharp front-wave transients, with rise times of the order of some tens of nanoseconds.

The voltage front-wave has an evolution that includes reflections, due to the mismatching of the characteristic impedance of HV circuits involved. In this respect, the resulting transient voltage and current in HV busbars are characterized by a fundamental oscillation frequency that depends on the length of the circuit and on the propagation time.

The oscillation frequency ranges from about 100 kHz to a few megahertz for open-air sub-stations, depending on the influence of the parameters mentioned above and the length of the busbars, which may vary from some tens of metres to hundreds of metres (400 m may occur).

In this respect, the oscillation frequency of 1 MHz may be considered representative of most situations, but 100 kHz has been considered appropriate for large HV substations.

The repetition frequency is variable between a few hertz and a few kilohertz depending on the distance between the switching contacts: that is, for close contacts, there is a maximum repetition frequency, while for distances between the contacts near to the extinction of the arc, the minimum repetition frequency, in respect of each phase, is twice the power frequency (100/s per phase for 50 Hz and 120/s per phase for 60 Hz HV systems).

The repetition rates selected, 40/s and 400/s, represent therefore a compromise, taking into account the different durations of the phenomena, the suitability of the different frequencies considered and the problem related to the energy to which the circuits under test are subjected.

In industrial plants, repetitive oscillatory transients may be generated by switching transients and the injection of impulsive currents in power systems (networks and electrical equipment).

The systems have a local response in a frequency band well covered by the rise time and the fundamental frequency of oscillation of the damped oscillatory wave selected for testing purposes.

4.2 Information on the fast damped oscillatory wave phenomenon

The fast damped oscillatory wave immunity test should cover phenomena present in two specific environments:

– substations of the power network (produced by switchgear and controlgear);

– all installations exposed to the high-altitude electromagnetic pulse (HEMP).

4.2.1 Disturbances produced by switchgear and controlgear

During opening or closing disconnector operations, between both contacts of the operated device, a large number of restrikes take place due to the slow speed of the contacts. Therefore, disconnector switch operations generate very fast transients, which propagate as travelling waves in the busbars of the substation. The electrical length of the shielded conductors and the length of the open circuit busbars determine the oscillation frequencies of the transient overvoltages.

For air insulated substations (AIS) these transients will radiate an electromagnetic field in the substation environment. Recent measurements have been performed in air insulated substations using instruments with a large frequency bandwidth [1])[1]. These measurements have shown that transient phenomena with frequencies higher than 1 MHz can also take place in these substations.

For gas insulated substations (GIS), these transients propagate inside the metallic enclosure, which contains the SF_6 gas. Due to the skin effect, high frequency transients are confined inside the enclosure and cause no problems. At the enclosure discontinuities however, a part of transients is transferred to the external surface of the enclosure tube. As a consequence, the enclosure potential rises and the current flowing on the enclosure surface radiates an electromagnetic field in the substation environment. The transient ground potential rise is a direct source of transient common mode currents in the secondary circuits. The radiated electromagnetic field also induces common mode currents in the secondary circuits.

1) Figures in square brackets refer to the bibliography.

Measurements have shown that the maximum frequency of significant components in the spectral density of these currents can be as high as 30 MHz to 50 MHz (see Figures 1 and 2) [2].

In Figures 1 and 2, it can be seen that several peaks occur in the current spectral density characteristic and important spectral components are observed at frequencies of some tens of MHz.

As summarized in [1], the frequency environment of HV substations (GIS, but also AIS) has become more severe than it was in the past, due to a reduction in distances as a consequence of the reduction of the overall sizes of substations, the use of gas insulated substations (GIS) and the installation of electronic equipment nearer to switching devices.

Therefore, the oscillation frequencies of 3 MHz, 10 MHz and 30 MHz for the fast damped oscillatory waves seem to be suitable to better take into account a more realistic environment both in some AIS and in all GIS.

The repetition frequency is variable between a few hertz and many kilohertz depending on the distance between the switching contacts: that is, with close contacts, there is a maximum repetition frequency, while for distances between the contacts near to the extinction of the arc, the minimum repetition frequency, in respect of each phase, is twice the power frequency (100/s per phase for 50 Hz and 120/s per phase for 60 Hz HV systems).

The repetition rate selected, 5 000/s, is set to consider the higher repetition rates measured in GIS. That rate still represents a compromise (as higher rates have been measured), taking into account the different duration of the phenomena, the suitability of the different frequencies considered and the problem related to the energy to which the circuits under test are subjected.

4.2.2 Disturbances produced by the high-altitude electromagnetic pulse (HEMP)

The high-altitude electromagnetic pulse (HEMP) as presented in IEC 61000-2-9 [4] describes an intense, plane wave electromagnetic pulsed field which has a rise time of 2,5 ns and a pulse width of approximately 25 ns. This field interacts with exposed cables and wiring to produce an oscillating voltage and current depending on the length of the line (see IEC 61000-2-10 [5]). For most external lines such as power and communications, these lines are long enough (often greater than 1 km) that the coupled currents and voltages are usually impulsive in nature.

For wires and cables inside of a building, the incident HEMP is partially attenuated, however, there is still enough field present to couple to short cables inside, providing a threat to connected electronic equipment. Experiments performed in the past clearly indicate that the HEMP fields couple to these short lines and produce high-frequency damped oscillatory waveforms with frequencies as high as 100 MHz, although frequencies below 30 MHz are the most usual (see IEC 61000-2-10). The damping rate of the oscillatory wave is fairly rapid due to the presence of absorbing walls in most buildings, and a resonance quality factor *Q* with a value between 10 and 20 is therefore typical.

It is also noted that short external wiring, such as those found as part of control circuits in power substations or at power plants are also likely to couple well to the HEMP fields. These cables will also exhibit damped oscillatory voltages in the range of 1 to 100 MHz depending on cable length.

Given that the HEMP environment is typically only one or two pulses, any test defined would not necessarily require a high repetition rate to replicate the incident environment. However, due to reliability concerns with digital electronics, it is recommended that a repetition rate similar to that recommended for switchgear and controlgear also be applied for HEMP (5 000/s) in order to increase the probability of discovering a malfunction. This is consistent with the fact that protection and testing to HEMP are ordinarily only performed when the consequences of electronic system failure are serious.

Concerning the HEMP immunity and generic standards that have been published to date (IEC 61000-4-25 [7] and IEC 61000-6-6), there is a need to have a basic test standard for the fast damped oscillatory wave containing information on test levels, the generator design, and test procedures that will permit one to carry out the tests necessary for the levels of voltages induced by a high-altitude electromagnetic pulse (HEMP). This voltage waveform is a fast damped sine wave that stresses the connected equipment. Although many frequencies are possible under realistic conditions, it has been decided that this fast oscillatory wave test should be carried out with oscillation frequencies up to 30 MHz in order to provide consistency with the environment produced in power network substations.

5 Test levels

The preferential range of test levels for the damped oscillatory wave tests, applicable to power, signal and control ports of the equipment, is given in Tables 1 and 2. The test level is defined as the voltage of the first peak (maximum or minimum) in the test waveform (Pk1 in Figure 1).

Different levels may apply to power, signal and control ports. The level(s) used for signal and control ports shall not differ by more than one level from that used for power supply ports.

Table 1 – Test levels for the slow damped oscillatory wave (100 kHz or 1 MHz)

Level	Common mode kV	Differential mode kV
1	0,5	0,25
2	1	0,5
3	2 [a]	1
4	-	-
x [b]	x	x

[a] The value is increased to 2,5 kV for substation equipment.

[b] x can be any level, above, below or in-between the other levels. This level can be given in the product standard.

Table 2 – Test levels for the fast damped oscillatory wave (3 MHz, 10 MHz or 30 MHz)

Level	Common mode kV
1	0,5
2	1
3	2
4	4
x [a]	x

[a] x can be any level, above, below or in-between the other levels. This level can be given in the product standard.

The applicability of the damped oscillatory wave test shall refer to the product specification.

The test levels from Tables 1 and 2 should be selected on the basis of the exposure to the primary phenomenon of the cables running in the installation. These levels are defined as an open circuit voltage either at the output of the generator or at the output of the CDN used.