IEC TR 61000-2-14

Edition 1.0 2006-12

TECHNICAL REPORT

RAPPORT TECHNIQUE

colour inside

Electromagnetic compatibility (EMC) –
Part 2-14: Environment – Overvoltages on public electricity distribution networks

Compatibilité électromagnétique (CEM) –
Partie 2-14: Environnement – Surtensions sur les réseaux de distribution publics

IEC TR 61000-2-14:2006-12(en-fr)

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INTERNATIONAL
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ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 2-14: Environment – Overvoltages on public electricity distribution networks

FOREWORD

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IEC 61000-2-14, which is a technical report, has been prepared by subcommittee 77A: Low frequency phenomena, of IEC technical committee 77: Electromagnetic compatibility.

This bilingual version (2019-03) corresponds to the monolingual English version, published in 2006-12.

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

Enquiry draft	Report on voting
77A/540/DTR	77A/547/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.

The French version of this standard has not been voted upon.

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

The committee has decided that the contents of this publication will remain unchanged until the maintenance result 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- withdrawn,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.

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INTRODUCTION

IEC 61000 is published in separate parts 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

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).

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 2-14: Environment – Overvoltages on public electricity distribution networks

1 Scope

This part of IEC 61000 describes the electromagnetic environment with respect to the voltages in excess of normal that are found on electricity supply networks operating at low and medium nominal voltages and that can be impressed on equipment connected to those networks, without considering further effects (e.g. amplification or attenuation) within an installation. Since these overvoltages have the potential to hinder the functioning of electrical and electronic equipment, they fall within the definition of *electromagnetic disturbance* in the field of EMC. Various categories of overvoltage are described, based on relative magnitude, duration and energy content.

This Technical Report describes the phenomena of overvoltages, it does not specify compatibility levels and does not directly specify emission and immunity levels.

The report describes the various phenomena and processes that cause overvoltages, including the transfer into the networks concerned of overvoltages that originate in or traverse other networks and installations, including higher voltage networks and the installations of electricity users. The effects of overvoltages on equipment are outlined. Some case studies of overvoltage events are presented.

Recommendations are made regarding the general technical approach to mitigating the risk of equipment being hindered from operating as intended by the effects of overvoltages. (It is not the function of IEC publications to assign responsibility for mitigating measures to any of the parties involved.)

The purpose of this report is to ensure that this important category of electromagnetic disturbance is included in the description of the environment in Part 2 of IEC 61000. For that purpose, only a brief description is provided of the various overvoltages and their causes and effects. A much more detailed treatment can be found in IEC 62066. A UIE publication – *Guide to quality of electrical supply for industrial installations, Part VI: Transient and temporary overvoltages and currents* – has a similar content. Measurement methods are specified in IEC 61000-4-30.

NOTE This Technical Report does not include detailed measurement results for overvoltages, therefore it is not possible to provide an assessment of the probability of occurrence.

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*

3 Terms and definitions

For the purposes of this document, the terms and definitions contained in IEC 60050-161 as well as the following terms and definitions apply.

3.1
back flashover
flashover of phase-to-earth insulation resulting from a lightning stroke to that part of the system which is normally at earth potential

3.2
breakdown
dielectric failure of an insulation under the effect of a strong electric field and/or by physico-chemical deterioration of the insulating material

3.3
direct lightning stroke
lightning striking a component of the network, e.g.: conductor, tower, substation equipment, etc.

3.4
declared supply voltage
U_c
normally the nominal voltage of the system. If by agreement between the electricity supplier and the consumer a voltage different from the nominal voltage is applied to the supply terminals, then this voltage is the declared voltage

3.5
disruptive discharge/flashover/sparkover
passage of an arc following dielectric breakdown

NOTE 1 The term "sparkover" (in French: "amorçage") is used when a disruptive discharge occurs in a gaseous or liquid dielectric.

NOTE 2 The term "flashover" (in French: "contournement") is used when a disruptive discharge occurs over the surface of a solid dielectric surrounded by a gaseous or liquid medium.

NOTE 3 The term "puncture" (in French: "perforation") is used when a disruptive discharge occurs through a solid dielectric.

3.6
indirect lightning stroke
lightning stroke that does not strike directly any part of the network but that induces an overvoltage in that network

3.7
insulation coordination
selection of the dielectric strength of equipment in relation to the operating voltages and overvoltages which can appear on the system for which the equipment is intended to operate, taking into account the service environment and the characteristics of the available prevention and protective devices

[IEV 604-03-08, modified]

NOTE In this instance, the term "dielectric strength of the equipment" means its rated or its standard insulation level as defined in IEC 60071-1.

3.8
lightning arrester
surge diverter
/surge arrester/
surge protective device (SPD)
device designed to protect the electrical apparatus from high transient overvoltages and to limit the duration and frequently the amplitude of the follow-on current

3.9
lightning impulse
voltage impulse of a specified shape applied during dielectric tests with a virtual front duration of the order of 1 μs and a time to half value of the order of 50 μs

NOTE The lightning impulse is defined by the two figures giving these durations in microseconds; in particular the standard lightning impulse is: 1,2/50 μs.

3.10
long duration overvoltages
overvoltage with a duration in excess of 10 min

NOTE The magnitude of a long duration overvoltage is typically given as a r.m.s. value.

3.11
nominal voltage
U**N**
the voltage by which a system is designated or identified

3.12
overvoltage
any voltage having a value, either peak or r.m.s., exceeding the maximum value of the corresponding declared voltage

3.13
per unit (p.u.)
methodology used to simplify equations and the presentation of electrical parameters by expressing them as a fraction of a reference parameter:

$$\text{p.u. value} = \left(\frac{\text{Actual}}{\text{Base}}\right)$$

where the Actual and Base values are of the same quantity, e.g. voltage, current, impedance etc.

NOTE Typically the Base value for voltage is the nominal voltage for fundamental frequency phenomena and the peak line to ground voltage for transients.

3.14
power frequency withstand voltage
r.m.s. value of sinusoidal power frequency voltage that the equipment can withstand during tests made under specified conditions and for a specified time

3.15
rise time (of a pulse)
the interval of time between the instants at which the instantaneous value of a pulse first reaches a specific lower value and then a specific upper value

NOTE Unless otherwise specified, the lower and upper values are fixed at 10 % and 90 % of the pulse magnitude.

3.16
short duration overvoltage
voltage swell
power frequency overvoltage with a duration lasting greater than one period (one cycle) and up to 10 min

NOTE The magnitude of a short duration overvoltage is typically given as a r.m.s. value.

3.17
surge
transient voltage wave propagating along a line or a circuit and characterized by a rapid increase followed by a slower decrease of the voltage

[IEV 161-8-11]

NOTE In some parts of the world the term "Impulse" is used to describe a short duration overvoltage characterised by a very rapid change in magnitude with a duration less than 200 µs.

3.18
temporary overvoltage
oscillatory overvoltage (at power frequency) at a given location, of relatively long duration and which is undamped or weakly damped

NOTE Temporary overvoltages usually originate from switching operations or faults (e.g. sudden load rejection, single-phase faults) and/or from non-linearities (ferroresonance effects, harmonics).

3.19
transient
pertaining to or designating a phenomenon or a quantity which varies between two consecutive steady states during a time interval short when compared with the time-scale of interest

[IEV 161-02-01]

3.20
very short duration overvoltage (transient)
overvoltage with a duration from less than a microsecond to several periods at fundamental frequency

NOTE The magnitude of a very short duration overvoltage is typically given as a peak value.

3.21
voltage impulse
transient voltage wave applied to a line or equipment, characterized by a rapid increase, followed generally by a slower non-oscillatory decrease of the voltage

3.22
front time
T_1
for a lightning impulse voltage T_1 is a virtual parameter defined as 1,67 times the interval T between the instants when the impulse is 30 % and 90 % of the peak value on the test voltage curve (points A and B, Figure 1)

3.23
time to half-value
T_2
for a lightning impulse voltage T_2 is a virtual parameter defined as the time interval between the virtual origin, O_1, and the instant when the test voltage curve has decreased to half the peak value

4 Description of overvoltages

4.1 General

Overvoltages are an intrinsic phenomena present on all networks. Overvoltage events can be created in the public network or in the electricity user's installation. The dynamic response of a network to load switching, both planned and unplanned (faults) will result in the storage and release of energy. This transfer of energy will cause an overvoltage to be propagated within the network.

4.2 External overvoltages

Overvoltages that are caused by events that are external to an installation, for example: lightning strokes and faults on adjacent higher voltage networks, are generally very short term overvoltage travelling waves. They attenuate with distance and the wave front becomes less steep. In addition there are longer term overvoltages caused by load rejection, open circuit neutrals, faulty voltage control equipment and the effect of distributed generation.

4.3 Internal overvoltages

Events within an installation can give rise to overvoltages, for example: the switching of non-linear load, switch arcing, and fuse operation.

4.4 Overvoltage waveshape

A common method of representing the waveshape of a very short term overvoltage is shown in Figure 1. The important values are the front time, T_1 and the time to half-value, T_2. For example, typical values for a transient overvoltage caused by lightning are 1,2 µs for the front time and 50 µs for the time to half-value (a 1,2/50 µs waveform).

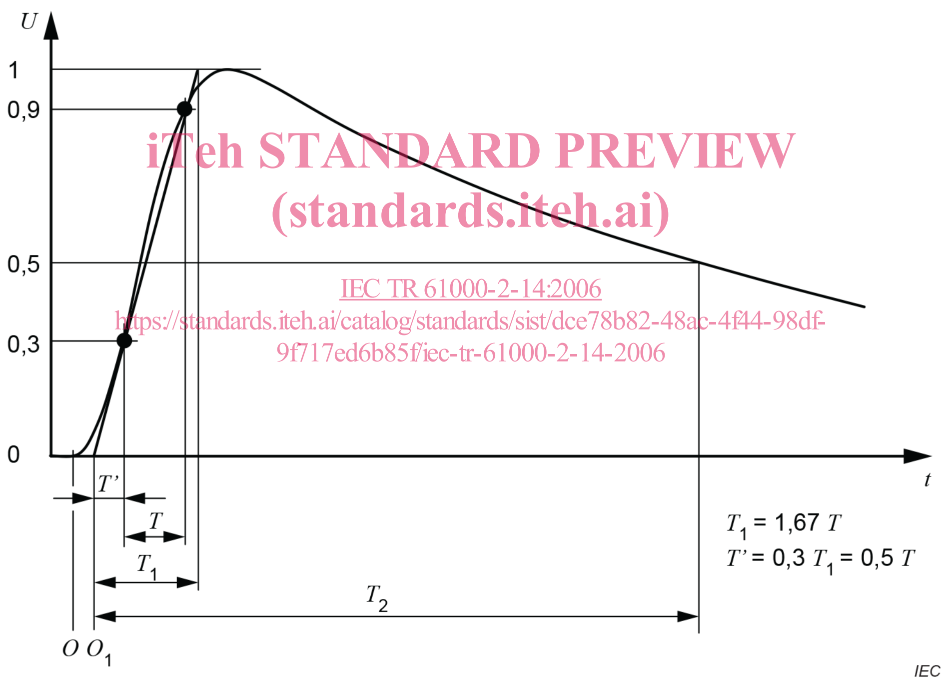

Figure 1 – Lightning impulse test voltage characteristic

NOTE Figure 1 is only meant to represent an example of one type of overvoltage. Other types of overvoltage are described in IEC 60071-2.

Other very short duration overvoltages having the shape of a damped high frequency oscillation can be caused by events such as energizing capacitor banks, although their amplitude is often much lower than an overvoltage caused by a lightning stroke, and the rate of occurrence can often be higher. This type of very short duration overvoltage can propagate over long distances and across voltage levels, hence adverse effects can often be seen some distance from the point of initiation. This is particularly true when the overvoltages are transferred to the lower voltage networks where the resilience of equipment is at its lowest. The situation at all voltage levels can be further exacerbated if a resonance condition is created, i.e. when the frequency of the transient overvoltage is close to the natural frequency of the network and or equipment connected to the network.

When more than one type of overvoltage event occurs simultaneously, it can lead to overvoltages in excess of the values quoted for a single event.

5 Long duration overvoltages

The overvoltages presented in this clause are typically described as being of long duration, however it should be noted that there will be instances where for a particular event the overvoltage could last for less than 10 min.

The overvoltages presented in this section are 50/60 Hz overvoltages.

5.1 Sustained earth faults

In MV networks with isolated or high-impedance grounded neutral, this kind of fault will produce line to earth temporary overvoltages on the healthy phases. The overvoltage will last for the duration of the fault, this can be anything from parts of a second for conventionally earthed systems up to some hours for systems earthed via a tuned reactance (Petersen coil earthing). Generally the magnitude of the overvoltage will not exceed twice the nominal phase to earth voltage, i.e. $\sqrt{3} \times U$, where U can be up to $1,1 \times U_N$ if the voltage is at the maximum of the acceptable MV range. The overvoltages last until the faulted section of network is disconnected.

Earth faults on the MV network can result in temporary power frequency overvoltages between live conductors and earth on the LV network. The duration and magnitude of these overvoltages will be dependent on the fault conditions and the MV earth impedance, as described above.

The majority of public LV distribution systems are operated with a solidly earthed (grounded) neutral. Therefore when earth faults occur on the MV network that raise the ground potential in the vicinity of the LV network it is possible for an overvoltage to exist between the phase and earth conductors of the LV network. The duration is limited by the time taken for the MV protection and circuit breaker to clear the fault, typically no more than 5 s. The magnitude of the overvoltage will generally not exceed 1,5 kV r.m.s., however this is dependent upon the impedance of the LV ground connection and the magnitude of the MV earth fault current. IEC 62066 contains a comprehensive description of this type of overvoltage.

5.2 Broken neutral on LV network

For a three-phase LV network supplied from a star (wye) transformer winding or for a two phase network supplied from a transformer with a centre-tapped neutral at LV (sometimes referred to as a three-wire network), if the neutral becomes disconnected (e.g. broken due to a fault), single-phase loads beyond the break could experience an overvoltage up to the line voltage of the network. The exact magnitude of the voltage will be dependent upon the ratio of the impedance (loads) connected across each phase of the network – see Figure 2 below. This type of overvoltage can persist for several hours or, in rare cases, days until the neutral has been reconnected or the faulty network has been disconnected in readiness for repair. This disconnection is often by manual intervention following complaints of severe voltage fluctuations which occur as a result of changes in load.

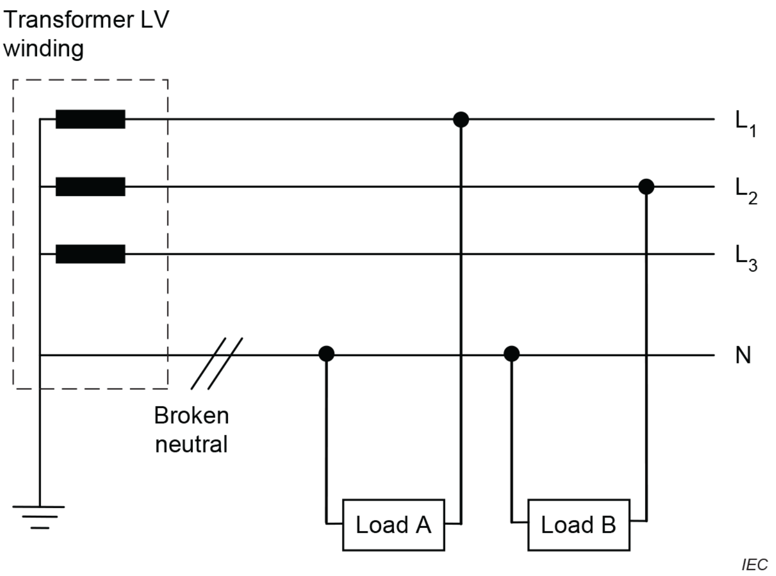

Figure 2 – Broken neutral on LV network

In the event of a broken neutral as shown in Figure 2 above, the voltage that appears across load A and load B is determined by the relative magnitude of these two loads, i.e.:

Voltage across load A (U_A) $= U_{L_1L_2}\left(\frac{Z_A}{Z_A + Z_B}\right)$; and

Voltage across load B (U_B) $= U_{L_1L_2} - U_A$

Hence, depending upon the values of Z_A and Z_B it is possible for U_A to vary between near zero and full line voltage ($U_{L_1L_2}$).

NOTE Depending on the impedances and their phase shift, the voltage on the unloaded phase, phase L_3 (L_3-N), could theoretically be higher than the full line voltage.

5.3 Maloperation of voltage regulating equipment

Maloperation of automatic voltage regulation systems can sometimes lead to long duration overvoltages between 1,1 and 1,2 p.u. at most. For instance, this could be due to a loss of regulator voltage reference causing the tap changer to boost the voltage at its maximum, or inadequate line drop compensation settings following unplanned load transfer on a regulating transformer. Appropriate voltage regulator blocking relays can minimize risks of such situations.

5.4 Overvoltages due to voltage unbalances

The combined effect of voltage unbalances and steady state voltage close to the maximum agreed voltage tolerance can result in long duration overvoltages. This is the case in particular for effectively earthed distribution systems supplying single-phase loads connected line-to-neutral through an equivalent Y-y earthed MV/LV transformer connection (typical in North America). In such cases, not only negative-sequence voltages can be transferred due to load unbalance, but also zero-sequence voltages as well. The latter also depends on the zero-sequence system impedance. In some cases, the combination of steady state voltages near the upper limit, and the negative-sequence plus the zero-sequence voltage unbalances can lead to permanent line-to-neutral voltages on some phases in the range of 1,1 p.u. at MV and LV. Voltage regulators whose voltage reference is connected line-to-neutral can however compensate the effect of zero sequence voltage unbalance thus reducing risks of this kind of overvoltage.