TECHNICAL REPORT

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Insulation coordination for equipment within low-voltage systems –

**Part 2-2:
Interface considerations –
Application guide**

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

INSULATION COORDINATION FOR EQUIPMENT WITHIN LOW-VOLTAGE SYSTEMS –

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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Technical reports do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful by the maintenance team.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 60664-2-2, which is a technical report, has been prepared by IEC technical committee 109: Insulation coordination for low-voltage equipment.

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

Enquiry draft	Report on voting
28A/168/CDV	109/2/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.

The committee has decided that the contents of this publication will remain unchanged until 2004. At this date, the publication will be

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- withdrawn;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

INTRODUCTION

This technical report provides guidelines for a common basis for IEC technical committees when considering interface issues in relation to insulation coordination. Surge protective devices are key elements in achieving a controlled overvoltage condition in low-voltage a.c. power systems and equipment. The aim of this guide is to avoid conflicting activities in the various committees involved and to achieve consistent requirements and guidelines. It deals with factors that influence the determination of overvoltage categories for installation and equipment.

A technical report IEC TR 62066 is being prepared by a joint working group (JWG) initially composed of representatives from the five IEC technical committees and subcommittees listed below and subsequently complemented by experts appointed by national committees and by CIGRE-CIRED.

SC 37A	Low-voltage surge-protective devices
TC 64	Electrical installations and protection against electric shock
SC 77B	High-frequency phenomena
TC 81	Lightning protection
TC 109	Insulation coordination for low-voltage equipment

Excerpts from IEC 62066 are included in order to identify information relevant to insulation coordination for low-voltage equipment.

INSULATION COORDINATION FOR EQUIPMENT WITHIN LOW-VOLTAGE SYSTEMS –

Part 2-2: Interface considerations – Application guide

1 Scope

This technical report provides an overview of the different kinds of surge overvoltages that can occur on low-voltage installations and equipment. In particular:

– the magnitude and duration of typical surges as well as their frequency of occurrence;

– information on overvoltages resulting from interaction between power and communication systems;

– guidelines when considering interface issues in relation to insulation coordination;

– guidelines concerning surge protection means on the basis of availability and risk considerations, including interaction within the system;

– highlights temporary overvoltages and other factors that have to be taken into account for insulation coordination, primarily related to protective control using surge protective devices.

2 Reference documents

IEC 60364-4-44, *Electrical installations of buildings – Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances*

IEC 60664-1, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

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

IEC TS 61312-3, *Protection against lightning electromagnetic impulse – Part 3: Requirements of surge protective devices (SPDs)*

IEC 61643-1, *Surge protective devices connected to low-voltage power distribution systems – Part 1: Performance requirements and testing methods*

IEC TR 62066, *General basic information regarding surge overvoltages and surge protection in low-voltage a.c. power systems* [1]

IEC 61643-12, *Surge protective devices connected to low-voltage power distribution systems – Part 12: Selection and application principles* [1]

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[1] To be published.

3 Definitions

For the purpose of this technical report, the following definitions apply.

3.1
overvoltage category
numeral defining an transient overvoltage condition

(IEC 60664-1, 1.3.10)

3.2
controlled overvoltage condition
condition within an electrical system wherein the expected transient overvoltages are limited to a defined level

(1.3.16 of IEC 60664-1)

3.3
inherent control
transient overvoltages limited by the electrical distribution system

3.4
protective control
transient overvoltages limited by devices such as surge protective devices (SPDs)

3.5
rated impulse voltage
impulse withstand voltage value assigned by the manufacturer to the equipment or a part of it, characterizing the specified withstand capability of its insulation against transient overvoltages

(IEC 60664-1,1.3.9.2)

4 Consideration of overvoltage categories

Insulation coordination for equipment relies on a series of steps. The first step is to determine the overvoltage category for the equipment (see IEC 60664-1, 2.2.2.1.1).

An overvoltage category is an indication of the degree of risk acceptable for the particular application. The overvoltage category can be determined by either knowledge of the inherent control or by use of protective control.

Protective control using SPDs could introduce an aspect of risk if the SPD fails or becomes ineffective. There are methods to indicate failure of an SPD and methods to automatically disconnect equipment from the supply system if it should fail. This latter method may be an appropriate in certain applications (see IEC 61643-1 and IEC 61643-12).

Determination of the overvoltage category leads to the selection of the rated impulse voltage using the tables in IEC 60664-1.

5 Consideration on the use of protective control

5.1 General

The installer will decide whether to provide protective control in an installation on the basis of local information (good practice), regulation etc.

Protective control of the equipment may be a decision taken either by the manufacturer or the user.

There are two significant elements in this decision-making process:

- the evaluation of the need for protective control, depending on the type of installation, the type and purpose of equipment and an assessment of the risks;
- the evaluation of the level of protective control against overvoltages for an indirect lightning strike. Overvoltages can be induced into the circuits of the installation or result from currents injected into medium-voltage or low-voltage systems by an indirect lightning strike at some distance from the installation. A similar evaluation is applicable to switching overvoltages.

More information is known about induced lightning overvoltages on low-voltage overhead lines than for inside building installations. Even less is known about overvoltages on equipment, including switching overvoltages. The estimated probability of overvoltages (number/year/km) represent the “prospective overvoltages“ (not influenced by any reaction of the system, such as a flashover). In practical cases, distortion and limitations are present due to multiple branches, cable sections, loads, flashovers, overvoltage protection devices, etc. The statistical distribution should therefore be expected to be somewhat modified in real cases. In particular, the frequency of overvoltages with magnitudes exceeding the normal line insulation level will be reduced.

From the reference data on the occurrence of overvoltages, more surge-related failures of equipment than what is actually being observed may be expected. This discrepancy can be explained by several factors:

- actual probability of the event at a given location;
- mitigating effect of multiple paths offered to the surges;
- actual behaviour of transmission lines;
- loading effect by linear as well as non-linear loads;
- presence of SPDs;
- unrecognized flashover due to very high overvoltages, etc.

One model used for analysis demonstrated that for a typical low-voltage line (230/400 V, twisted cable, three-phase and neutral), and for a flash density of 2,2 flashes per year per kilometre, the prospective number of overvoltages exceeding the insulation level of 4 kV for a 230 V TN system, such as 4 kV for a 230 V TN system, is in the order of one occurrence every other year. However, even such a low frequency of overvoltage occurrence may not be acceptable if it results in failure within an installation or of critical equipment. Therefore, the degree of acceptable risk must be taken into consideration for each situation.

Overvoltages between conductors and local earth stress the insulation of connected equipment which usually has sufficient withstand level in accordance with IEC 60664 -1, while the working components of power equipment are stressed by overvoltages appearing between conductors. Initially, it might be concluded that the most threatening situation would be the overvoltages applied to the working components of the power equipment. However, overvoltages to earth can become a problem, not so much for the power equipment insulation, but as a result of shifts in reference potential between the power system and the communication system that might be connected to the equipment. This potential problem is discussed in greater detail in clause 8 and annex D of IEC 62066.

5.2 Recapitulation on lightning overvoltages

Lightning overvoltages originate from a source beyond human control and their severity at the point of utilization of electric power depends on many parameters determined by the point of impact of the lightning strike and by the structure of the power system. This structure is generally determined by considerations other than lightning protection.

The overvoltages may be classified according to their point of impact: direct flashes, near flashes and flashes occurring at some distance. For direct flashes, the overvoltages result from the flow of lightning current in the structure and the associated earthing system. For near flashes, the overvoltages result from induction of voltages in the conductor loops and to some extent the rise in earth potential associated with the lightning current. For far flashes, the overvoltages are limited to those induced into circuit loops.

It should be noted that IEC 60664-1 does not cover the aspect of direct flashes or near flashes. Increasing stresses occur when the point of impact of the lightning strike is closer to the structure of interest, but the likelihood of such high stress is less than that of a stress of lower magnitude associated with more remote flashes. In any case, statistical considerations, which are discussed in IEC 62066 under clauses dealing with risk analysis, are an essential part of the decisions to be made concerning protection against these lightning overvoltages.

Lightning occurrences and lightning characteristics are of a statistical nature, and there are still uncertainties involved. For instance, most direct current measurements have been made for high towers, and the results might not, in general, be representative. The geographical area, including climatic conditions, can also be decisive. Measurements as well as theoretical studies are still going on in several parts of the world, and more reliable data on lightning and lightning effects are expected in the future.

It should be noted that any proposal for applying theoretical considerations or results of limited measurements in order to define a relationship between probability of occurrence and levels should always be reconciled with reality checks. Guidance for probability of occurrence and levels is given by TC64.

6 Observations on surge overvoltages and failure rates

6.1 General

Consideration of the three types of overvoltages (lightning, switching, and temporary) presents quantitative information on these phenomena, based in part on theory that makes assumptions on the prevailing situation, and in part on measurements. Field measurements can only reflect local conditions at the time of the measurement; laboratory measurements can only provide conclusions based on the assumptions underlying the experimental set-up.

Notes in IEC 62066 state that broad generalizations from limited data should not be made without some caution. Such caution is more a qualitative than quantitative process, calling for a reconciliation between predictions on the frequency of occurrence of “large” surges and the reality of field performance of equipment that are subject to the surges that actually occur in their environment.

Another qualitative caution is the reconciliation between the conclusions drawn from the sometimes simplified assumptions made for computations and the basic laws of physics. Any conclusion based on these simplifications, generalizations or assumptions, which does not match reality, should be a call for caution on the validity of these simplifications, etc. Therefore, the following observations are presented as a measure of experience-based caution. They do not purport to deny the occurrence of “large” surges, but only to suggest that these “large” surges do not occur as frequently as the limited available information might suggest.

6.2 Using field failure data

Unfortunately, there are no extensive failure statistics available for low-voltage equipment, and it is difficult to estimate the failure rate in an objective way. Nevertheless, some investigations made by insurance companies, based on their internal statistics, indicate that equipment failures (video equipment, refrigerators, etc.) occur relatively frequently during thunderstorms, especially in areas with overhead low-voltage distribution lines. Indications have also been found that minor damage caused by leakage currents occur without breaker or fuse operation, producing the ultimate failure hours or days after the initial surge event. Reasons for these equipment failures include:

- insufficient surge capability at the equipment power input port;
- lack of insulation coordination;
- ageing of equipment;
- system interaction.

While manufacturers are sometimes reluctant to publish their failure data, anecdotal information does often provide some indication of the survival of equipment under actual field conditions.

If the surge immunity levels, or failure levels, of equipment are known, one can make inferences on the order of magnitude of the frequency of occurrence of surges above that immunity level. A high rate of failure would indicate a corresponding rate of occurrence of surges above that level. When the field experience shows in fact a low failure rate, one can infer an equally low rate of surge occurrence above the equipment failure level.

6.3 Preventing permanent damage

Application of SPDs is generally focussed on a consideration to prevent damage caused by the amplitude and energy-delivery capability of a surge (including the duration of the surge) while interference generally reflects the parameters of the front of the surge. When the situation involves an overvoltage resulting from inductive effects associated with a surge current, the rate of current change, the front of the surge, is the relevant factor for the resulting overvoltage.

Of course, preventing permanent damage can also be achieved by raising the inherent immunity level of the equipment. This is the approach suggested in IEC 60664-1 where the "equipment withstand voltage" is defined and several categories of withstand levels are identified, as discussed below.

It should be kept in mind, however, that "insulation withstand" generally refers to overvoltages occurring in the line-to-earth mode (a form of common mode), while electronic components are generally connected line-to-neutral (also described as "differential mode"). Neutral earthing practices, which vary from country to country, also play a role in the relative levels of surge threats in the common mode versus the differential mode. For instance, in TN systems, the bonding of the neutral and earth at the service entrance prevents further propagation of common mode surges impinging upon the installation, by converting them to differential (line-to-neutral) surges. Many IEC publications defining surge environments. For example, IEC 61000-4-5 suggests that immunity tests should have a level for common mode surge higher than that for differential mode. However, the overvoltages to be expected in a TN system are generally lower compared to a TT system, due to the multiple earthing of the neutral conductor.

Notwithstanding these subtle differences, the following paragraphs summarize the approach taken in IEC 60664-1, where a direct relation is established between equipment impulse withstand voltages and an overvoltage category assigned to the equipment. This relation is independent of the physical location of the equipment in the particular installation.

The overvoltage category, which characterizes the impulse withstand level of equipment, allows the classification of equipment and their selection according to the necessity of service continuity and an acceptable possibility of failure. Together with the preferred rated impulse voltages, they make insulation coordination possible for the whole installation, reducing the possibility of failure to an acceptable level and providing a basic overvoltage withstand capability.

A higher level of overvoltage category indicates a better withstand of the equipment and provides wider choice of a method for overvoltage protection. After their front, for which characteristic impedances prevail, overvoltages of atmospheric origin are not significantly attenuated downstream from the service entrance when relatively high impedance loads are connected to the branch circuits. Studies show that it is reasonable to use probabilistic analysis to evaluate the need for protection.