TECHNICAL REPORT

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First edition
2004-06

Insulation co-ordination –

Part 4: Computational guide to insulation co-ordination and modelling of electrical networks

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International Electrotechnical Commission, 3, rue de Varembé, PO Box 131, CH-1211 Geneva 20, Switzerland
Telephone: +41 22 919 02 11 Telefax: +41 22 919 03 00 E-mail: inmail@iec.ch Web: www.iec.ch

Commission Electrotechnique Internationale
International Electrotechnical Commission
Международная Электротехническая Комиссия

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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INSULATION CO-ORDINATION –

Part 4: Computational guide to insulation co-ordination and modelling of electrical networks

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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The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a technical report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

IEC 60071-4, which is a technical report, has been prepared by IEC technical committee 28: Insulation co-ordination.

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

Enquiry draft	Report on voting
28/156/DTR	28/158/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 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

- transformed into an International standard
- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

A bilingual version of this technical report may be issued at a later date.

INSULATION CO-ORDINATION –

Part 4: Computational guide to insulation co-ordination and modelling of electrical networks

1 Scope and object

This technical report gives guidance on conducting insulation co-ordination studies which propose internationally recognized recommendations

– for the numerical modelling of electrical systems, and
– for the implementation of deterministic and probabilistic methods adapted to the use of numerical programmes.

Its object is to give information in terms of methods, modelling and examples, allowing for the application of the approaches presented in IEC 60071-2, and for the selection of insulation levels of equipment or installations, as defined in IEC 60071-1.

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 60060-1:1989, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60071-1:1993, *Insulation co-ordination – Part 1: Definitions, principles and rules*

IEC 60071-2:1996, *Insulation co-ordination – Part 2: Application guide*

IEC 60076-8:1997, *Power transformers – Part 8: Application guide*

IEC 60099-4:1991, *Surge arresters – Part 4: Metal-oxide surge arresters without gaps for a.c. systems* [1]

IEC 61233:1994, *High-voltage alternating current circuit-breakers – Inductive load switching*

3 Terms and definitions

For the purposes of this document, the following terms and definitions, in addition to those contained in IEC 60071-1, apply.

NOTE Certain references are taken from the IEC Multilingual Dictionary[1] [2].

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1 A consolidated edition exists, published in 2001, which incorporates the current edition, plus its amendment 1 (1998) and amendment 2 (2001).

2 References in square brackets refer to the bibliography.

3.1
backfeeding
refers to the conditions of supplying a high-voltage overhead line or cable through a transformer from the low-voltage side

3.2
back flashover
flashover of phase-to-earth insulation resulting from a lightning strike to towers and shielding wires [1]

3.3
back flashover rate
number of back flashovers of a line per 100 km per year

3.4
closing of capacitive load
essentially closing of capacitor banks but also closing of any other capacitive load

3.5
critical current
minimum lightning current that induces a flashover on a line

NOTE The critical current of the line is the smallest critical current among all injection points.

3.6
direct lightning strike
lightning striking a component of the network, for example, conductor, tower, or substation equipment [1]

3.7
energization
connecting or reconnecting to a source an element of a power system which has no stored energy

3.8
fault clearing
interruption of the short-circuit condition on a system

3.9
limit distance
distance from the substation after which no overvoltage resulting from a lightning stroke gives rise to an impinging surge dangerous for the substation's equipment

3.10
line dropping
disconnection of the line by opening the last circuit-breaker

3.11
line fault application
application of a line short-circuit on a system

3.12
load rejection
opening of a line breaker during normal power flow causing a certain amount of load to be unsupplied

NOTE From a temporary overvoltage point of view, the worst case occurs when the remote circuit-breaker of a long line transmitting a significant part of the supply of a power station is opened.

3.13
line re-energization
opening and fast closing of the line circuit-breaker as the consequence of a fault or a relay maloperation

NOTE With respect to line energization, trapped charges should be taken into account.

3.14
maximum shielding current
maximum lightning current that can hit a phase conductor on a line protected by shielding wires

3.15
parallel line resonance
overvoltage appearing on an unenergized shunt reactor compensated circuit due to capacitive coupling with a parallel energized circuit

3.16
point-on-cycle controlled switching
energization of capacitive load at the instant that the voltage is zero across the circuit-breaker contacts thus eliminating the switching transient

NOTE De-energization of inductive load ensures a long and weak power arc at zero-current crossing thus eliminating the risk of re-strike and re-ignition.

3.17
representative lightning stroke current
minimum value of lightning current at a specific point of impact which produces overvoltages that the equipment has to withstand; it is deduced from experience

3.18
slow-front overvoltage flashover rate
number of flashovers of a line per 100 km per year due to slow-front overvoltages

3.19
switching resistor
resistance inserted to match the surge impedance of the line in order to limit the switching surge magnitude launched from the source

3.20
switching of inductive and capacitive current
includes interruption of starting current of motors, interruption of inductive current when interrupting the magnetizing current of a transformer or when switching off a shunt reactor, switching and operation of arc furnaces and their transformer, switching of unloaded cables and of capacitor banks, interruption of current by high-voltage fuses

(See 2.3.3.4 in IEC 60071-2)

3.21
uneven breaker pole operations
operation caused by one or two breaker poles stuck during opening or closing of the circuit-breaker

4 List of symbols and acronyms

AIS	Air-insulated substation
BFO	Back flashover
BFR	Back flashover rate
EGM	Electro-geometric model
FACTS	Flexible alternating current transmission systems
FFO	Fast-front overvoltages
GIS	Gas-insulated system
HVDC	High-voltage d.c.
LIWV	Lightning impulse withstand voltage
MOA	Metal oxide surge arrester
SFO	Slow-front overvoltages
SIWV	Switching impulse withstand voltage
SFOFR	Slow-front overvoltage flashover rate
TOV	Temporary overvoltages
TRV	Transient recovery voltage
VFFO	Very-fast-front overvoltages
Z_s (or Z_c)	Surge (or characteristic) impedance
I_c	Critical current
I_m	Maximum shielding current

In addition, refer to 1.3 of IEC 60071-2 as well as the list of symbols in [4].

5 Types of overvoltages

Table 1, extracted from IEC 60071-1, and Figure 1, detail the characteristics of all types of overvoltages.

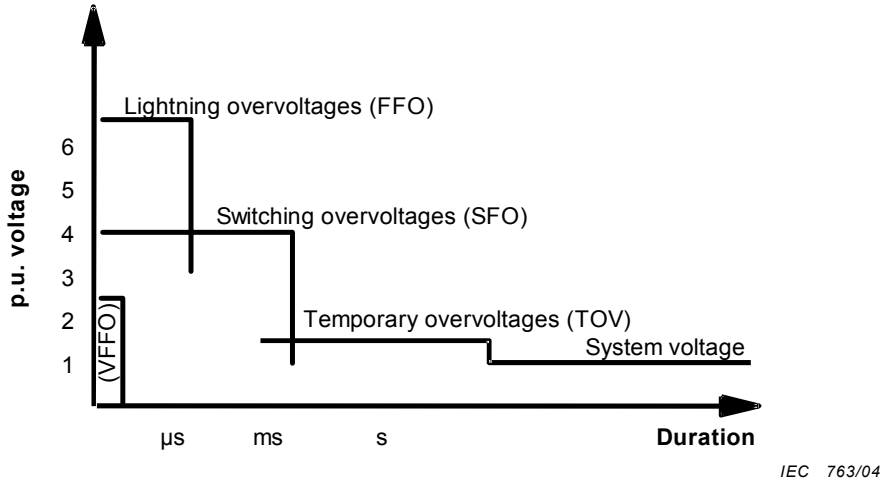
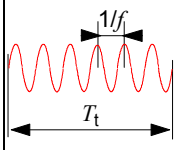
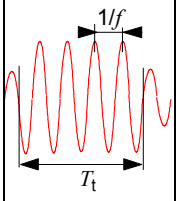
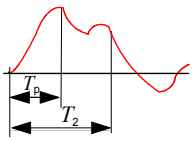
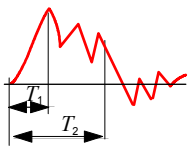
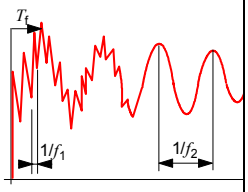
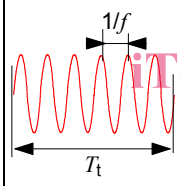
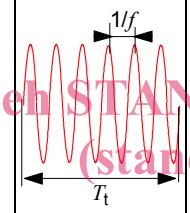
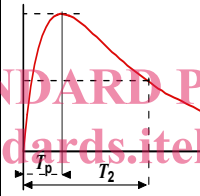
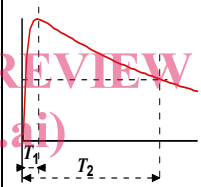


Figure 1 – Types of overvoltages (excepted very-fast-front overvoltages)

Table 1 – Classes and shapes of overvoltages – Standard voltage shapes and standard withstand tests

Class	Low frequency		Transient		
	Continuous	Temporary	Slow-front	Fast-front	Very-fast-front
Voltage or over-voltage shapes					
Range of voltage or over-voltage shapes	f = 50 Hz or 60 Hz $T_t \geq 3\,600$ s	10 Hz < f < 500 Hz 0,03 s ≤ T_t ≤ 3 600 s	20 µs < T_p ≤ 5 000 µs T_2 ≤ 20 ms	0,1 µs < T_1 ≤ 20 µs T_2 ≤ 300 µs	3 ns < T_f ≤ 100 ns 0,3 MHz < f_1 < 100 MHz 30 kHz < f_2 < 300 kHz
Standard voltage shapes					1)
	f = 50 Hz or 60 Hz T_t 1)	48 Hz ≤ f ≤ 62 Hz T_t = 60 s	T_p = 250 µs T_2 = 2 500 µs	T_1 = 1,2 µs T_2 = 50 µs	
Standard withstand test	1)	Short-duration power frequency test	Switching impulse test	Lightning mpulse test	1)

1) To be specified by the relevant apparatus committees.

6 Types of studies

For range I voltage level (U_m up to 245 kV), SFO are generally not critical while the FFO due to lightning have to be carefully considered. However, for higher voltage levels, SFO become of major importance, specifically in the UHV range, while FFO become in many cases less critical.

TOV have to be studied for all system voltage levels.Table 2 provides a list of events and the most critical types of overvoltages generated.