

# TECHNICAL SPECIFICATION

**Instructions for simulation-based insulation coordination and modelling of  
electrical networks**

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# Instructions for simulation-based insulation coordination and modelling of electrical networks

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IEC TS 60071-4 has been prepared by IEC technical committee 99: Insulation co-ordination and system engineering of high voltage electrical power installations above 1,0 kV AC and 1,5 kV DC. It is a Technical Specification.

This edition cancels and replaces IEC TR 60071-4, published in 2004. This edition constitutes a technical revision

The text of this Technical Specification is based on the following documents:

| Draft      | Report on voting |
|------------|------------------|
| 99/535/DTS | 99/548/RVDTS     |

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Specification is English.

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## 1 Scope

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

- for the computational 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 that support the application of the approaches presented in IEC 60071-2:2023, and for the selection of insulation levels of equipment or installations, as defined in IEC 60071-1:2019.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 60060-1:2025, *High-voltage test techniques - Part 1: General terminology and test requirements*

IEC 60071-1:2019, *Insulation co-ordination - Part 1: Definitions, principles and rules*

IEC 60071-2:2023, *Insulation co-ordination - Part 2: Application guidelines*

IEC 60071-11:2022, *Insulation co-ordination - Part 11 : Definitions, principles and rules for HVDC system*

IEC 60071-12:2022, *Insulation co-ordination - Part 12: Application guidelines for LCC HVDC converter stations*

IEC 60099-4:2014, *Surge arresters - Part 4: Metal-oxide surge arresters without gaps for a.c. systems*

IEC 62271-100:2021, *High-voltage switchgear and controlgear - Part 100: Alternating-current circuit-breakers*

## 3 Terms and definitions, symbols and acronyms

For the purposes of this document, the terms and definitions given in IEC 60071-1:2019 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

NOTE Certain references are taken from the IEC Electrotechnical Vocabulary (<https://www.electropedia.org>).

### 3.1 Terms and definitions

#### 3.1.1

##### **back-feeding**

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

**3.1.2****back flashover****BFO**

flashover of line-to-earth insulation resulting from a lightning strike to that part of the system, which is normally at earth potential, e.g. towers and shielding wires

[SOURCE: IEC 60050-614:2016 [1], 614-03-41, modified - "e.g. towers and shielding wires" has been added.]

**3.1.3****back flashover rate****BFR**

number of back flashovers of a line per 100 km per year

**3.1.4****energization**

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

**3.1.5****fault clearing**

interruption of the short-circuit condition on a system

**3.1.6****highest voltage of a system** $U_s$ 

highest value of phase-to-phase operating voltage (RMS value) which occurs under normal operating conditions at any time and at any point in the system

[SOURCE: IEC 60050-601:1985 [2], 601-01-23, modified - Clear meaning on the voltage has been added, the note has been deleted.]

**3.1.7****highest voltage for equipment** $U_m$ 

highest voltage of phase-to-phase voltage (RMS value) for which equipment is designed in respects of its insulation as well as other characteristics which relate to this voltage in the relevant equipment standards

[SOURCE: IEC 60050-614:2016 [1], 614-03-01, modified - "greatest value of line-to-line voltage" has been replaced by "highest voltage of phase-to-phase voltage" and "under normal service conditions" has been deleted.]

**3.1.8****limit distance** $X_p$ 

distance from the substation beyond which overvoltages resulting from a lightning stroke are attenuated to levels that do not pose a risk to the substation's equipment insulation

**3.1.9****line dropping**

disconnection of the line by opening the last circuit-breaker

**3.1.10****line fault application**

application of a line short-circuit on a system

**3.1.11****load rejection**

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

Note 1 to entry: 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.

**3.1.12****line re-energization**

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

Note 1 to entry: With respect to line energization, trapped charges should be taken into account in detailed studies.

**3.1.13****parallel line resonance**

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

**3.1.14****representative lightning stroke current**

minimum value of lightning current at a specific point of impact which produces overvoltages that the equipment has to withstand

**3.1.15****switching resistor**

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

**3.1.16****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

Note 1 to entry: See IEC 60071-2:2023 [3], 5.3.3.5.

**3.1.17****non-simultaneous pole operation**

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

**3.2 Symbols and acronyms**

|       |                                                                            |
|-------|----------------------------------------------------------------------------|
| AC    | alternating current                                                        |
| BFO   | back flashover                                                             |
| BFR   | back flashover rate                                                        |
| DC    | direct current                                                             |
| EGM   | electro-geometric model                                                    |
| EMTP  | electromagnetic transients programme                                       |
| F     | frequency                                                                  |
| FACTS | flexible alternating current transmission systems                          |
| FFO   | fast-front overvoltages                                                    |
| GIS   | gas-insulated system / gas-insulated switchgear / gas-insulated substation |
| HVDC  | high voltage DC                                                            |
| $I_c$ | critical current                                                           |

|                   |                                     |
|-------------------|-------------------------------------|
| $I_m$             | maximum shielding current           |
| LIWV              | lightning impulse withstand voltage |
| MTBF              | mean time between failures          |
| MOA               | metal oxide surge arrester          |
| RMS               | root mean square                    |
| SFO               | slow-front overvoltages             |
| TOV               | temporary overvoltages              |
| TRV               | transient recovery voltage          |
| UMEC              | unified magnetic equivalent circuit |
| VFFO              | very-fast-front overvoltages        |
| $Z_s$ (or $Z_c$ ) | surge (or characteristic) impedance |

In addition, refer to IEC 60071-2:2023, 3.2 as well as the list of symbols in CIGRE WG 4.23 [4].

#### 4 Types of overvoltages

Table 1, extracted from IEC 60071-1:2019 [5], and Figure 1, detail the characteristics of all types of overvoltages.

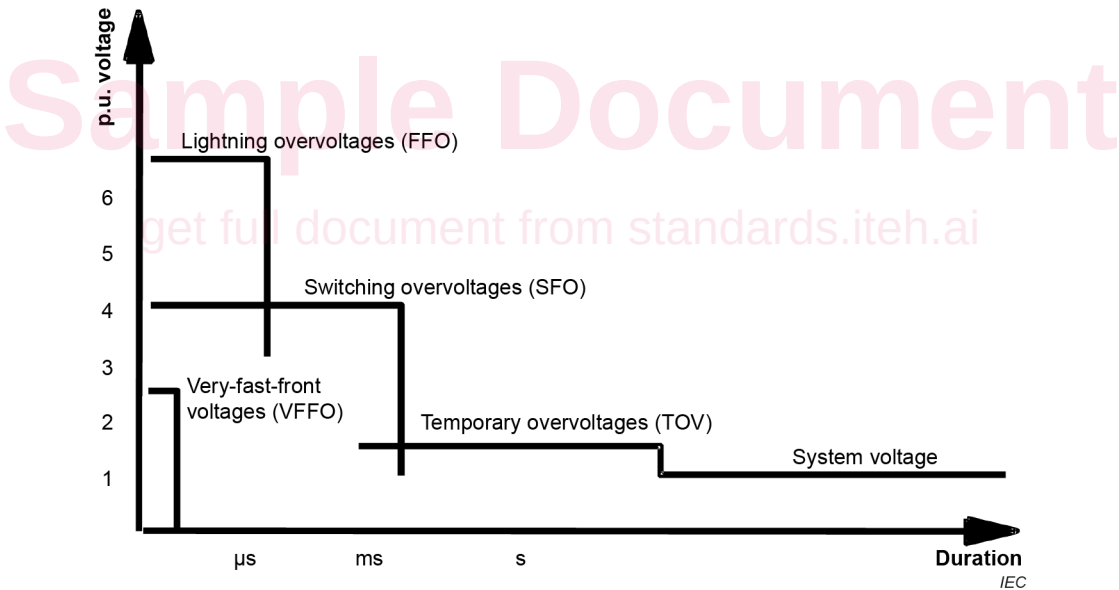
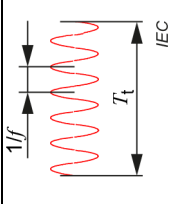
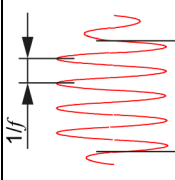
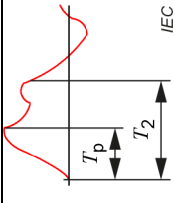
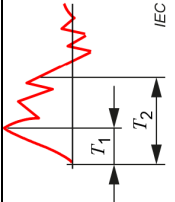
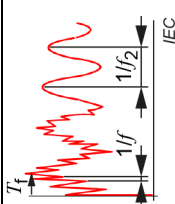
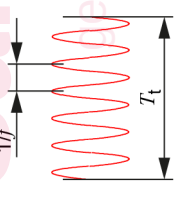
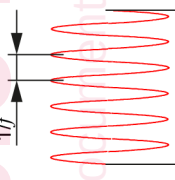
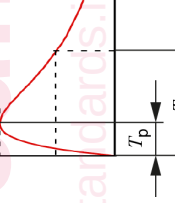
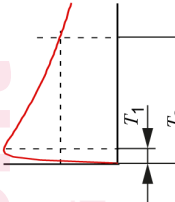


Figure 1 – Types of overvoltages

**Table 1 – Classes and waveforms of overvoltages - Standard voltage waveforms and standard withstand tests**  
(taken from IEC 60071-1:2019 [5])

| Class                                                   | Low frequency                                                                       |                                                                                        | Slow-front                                                                         | Transient<br>Fast-front                                                           | Very-fast-front                                                                                                                   |
|---------------------------------------------------------|-------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|
|                                                         | Continuous                                                                          | Temporary                                                                              |                                                                                    |                                                                                   |                                                                                                                                   |
| Voltage or overvoltage waveforms                        |  |     |  |  |                                                  |
| Range of voltage or overvoltage waveforms               | $f = 50 \text{ Hz or } 60 \text{ Hz}$<br>$T_t \geq 3 \text{ 600 s}$                 | $10 \text{ Hz} < f < 500 \text{ Hz}$<br>$0,02 \text{ s} \leq T_t \leq 3 \text{ 600 s}$ | $20 \mu\text{s} < T_1 \leq 5 \text{ 000 } \mu\text{s}$<br>$T_2 \leq 20 \text{ ms}$ | $0,1 \mu\text{s} < T_p \leq 20 \mu\text{s}$<br>$T_2 \leq 300 \mu\text{s}$         | $3 \text{ ns} < T_1 \leq 100 \text{ ns}$<br>$0,3 \text{ MHz} < f_1 < 100 \text{ MHz}$<br>$30 \text{ kHz} < f_2 < 300 \text{ kHz}$ |
| Standard voltage waveforms                              |  |     |  |  | a                                                                                                                                 |
|                                                         | $f = 50 \text{ Hz or } 60 \text{ Hz}$<br>$T_t^a$                                    | $48 \text{ Hz} \leq f \leq 62 \text{ Hz}$<br>$T_t = 60 \text{ s}$<br>b                 | $T_1 = 250 \mu\text{s}$<br>$T_2 = 2 \text{ 500 } \mu\text{s}$<br>b                 | $T_1 = 1,2 \mu\text{s}$<br>$T_2 = 50 \mu\text{s}$<br>b                            |                                                                                                                                   |
| Standard withstand test                                 | a                                                                                   | Short-duration power frequency test<br>b                                               | Switching impulse test<br>b                                                        | Lightning impulse test<br>b                                                       | a                                                                                                                                 |
| a To be specified by the relevant apparatus committees. |                                                                                     |                                                                                        |                                                                                    |                                                                                   |                                                                                                                                   |
| b To be specified by IEC 60060-1:2025.                  |                                                                                     |                                                                                        |                                                                                    |                                                                                   |                                                                                                                                   |