Annex 1 - Draft Guide

Edition 0.0

GUIDE

Guidelines for the use of simulations and calculations used in IEC products standards.

Lignes directrices pour l'utilisation de simulations et de calculs spécifiés dans les normes IEC

CONTENTS

FOREWORD

Laboratory type testing, as specified in product standards, is the most efficient way to verify if a certain product attends the technical standard specification. High power tests like the internal arc tests, temperature rise test and short time withstand current test are onerous and time consuming. There are relatively few laboratories in the World with capacity to do them.

Testing simulation techniques are used to predict results of several type tests. In many cases they enable to obtain more complete information than the information which could be obtained in a real laboratory testing.

Simulations can be applied in situations like: (a) to avoid switchgear tests in equipment with characteristics near to another one already tested or (b) to enable the certification of products in countries with low testing laboratories availability or (c) to replace SF_6 by air in some tests.

Within certain limits, testing simulation can be used to extrapolate the results of an already done laboratory test to other, with similarities, untested equipment. This can be made in an easier or more complex way depending on the type of test.

As an example, for temperature rise tests on bus bar systems, the use of simulation to replace a test is relatively simple to perform. Even with relatively simple calculation methods it is possible to obtain calculated values near to the values obtained during the real tests.

For internal arcs tests in switchgear the task is more complex but possible. What is to be checked during the tests are the effects of the overpressures arising during the arc and the risks to persons in the neighborhood. The curve overpressure x time is the decisive agent for the good or bad test result and shall be registered during laboratory tests.

For short-time withstand current and peak withstand current tests the objective is to verify the supportability to the effects of electrodynamical forces on insulators and conductors occurring during a short circuit without arc. To calculate the forces and stresses is not a so complex task but to measure them is very difficult and onerous. Nevertheless the calculation methods are used for many decades and well accepted in the technical world.

The difficulties to validate some simulation methods are mainly because some relevant parameters are not yet requested to be measured during laboratory tests. This Guide show the main parameters which shall be registered during laboratory tests to enable a future use of simulations for the extrapolation of test results.

GUIDELINES FOR THE USE OF SIMULATIONS AND CALCULATIONS TO REPLACE SOME TESTS SPECIFIED IN INTERNATIONAL STANDARDS

1 Scope

This Guide presents Guidelines for the systematization of the use of simulations and calculations (from now on named “simulations”) which may be used to replace some laboratory tests in situations where the common sense shows it is reasonable to use it. The most frequent case of such use of simulations is in the extrapolation of real test results done in a certain equipment to predict the results of a test in untested equipment with characteristics close to the tested one.

The use of simulations to replace tests is possible only when certain specific measurements and registers are specified in the relevant product standards and are presented in the laboratory test report. This Guide specifies minimum measurements and photographic registers that shall be done and registered in test reports, during laboratory tests specified in product standards.

These measurements make the test to be reproducible and usable for future simulations. These measurements and registers also help users to identify if a commercialized product is similar to the laboratory tested one.

Currently, there is a lack of data for the validation of simulations results by comparison with real test results. It is expected that with few simple additional measurements and registers here specified, to be used in product standards, the amount of available data will increase significantly, in the short term.

This Guide presents some examples of input data and results which can be used as a calibration to demonstrate that a certain simulation model is acceptable for the extrapolation of the laboratory test results..

It is not an objective of this Guide to present calculation methods for testing simulation. It is considered that a model or method is acceptable when it produces validated simulation results within acceptable tolerances if compared with the real test results and this can be demonstrated in a transparent way to the users.

The acceptance of simulations results by users is easier when the number of input variables of the simulation model is lower and they are based in the geometry and materials properties of the conductors, insulation and fluids. The reproducibility of the calculation method is the key point.

Although the simulation concepts here presented are valid for any electrical equipment, in the current stage, the simplest visible applications of it are in high and low voltage switchgear, transformers, fuses and bus-bar systems.

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.

ISO/IEC Directives, Part 2:2004, Rules for the structure and drafting of International Standards

3 Definitions

For the purposes of this Guide, the following definitions apply.

3.1 - Simulation or calculation to replace a test and acceptable tolerances

A calculation method used to predict, within a certain specified tolerance, the results which would occur in a laboratory test as specified in the relevant product standard.

Typical values of acceptable tolerances of the results to be obtained in the simulations if compared to the real laboratory test results are:

Type of test	Parameter to compare	Typical values of acceptable tolerance for the calculated values
Temperature rise test	Temperature rise in solid and fluid parts	1% to 5%
Internal arc test	Overpressure in the enclosure above the atmospheric pressure (crest and duration)	5% to 10%
Short-time withstand current and peak withstand current tests	Electrodynamical forces and mechanical stresses	5% to 15%

3.2 - Product publication

Publication covering a specific product or group of related products

3.3 - Reproducibility of a simulation or calculation method

The capability of to obtain, for a specified set of input data the same test results or the same simulation results in two ore more different occasions or two different test laboratories.

3.4 - Validation of a simulation or calculation method or a laboratory test

A method of comparison between the results showed in a well documented test report issued at a test laboratory and the results of a simulation method. A simulation method is generally acceptable, from the point of view of users, when it is reproducible and gives a difference between simulation and laboratory results not higher than a certain acceptable tolerance.

3.5 - Minimum input data to be registered in temperature rise laboratory test reports

Equipment is approved during a test if the final measured temperature rises of the parts do not go beyond certain limits dictated by the properties of the insulating and conductive parts. These limits are showed in the relevant product standard. IEC TR 60943 and IEC 60890 explain the concepts involved.

The data affecting the test and the simulations results are

- -the circulating electric current,
- -the total power dissipation inside the fluid compartment

-the materials used in the conductor and insulating parts
-the contact resistances and its coatings (total per phase and also the ones of the individual parts like circuit breakers, fuses , isolators)
-the ambient gas or liquid fluid temperature (for example at the bottom , the top and at 50% of the height of the enclosure),
-the fluid velocity
-the geometry and spatial position of the conductors
-the volume of fluid inside the compartments
-The input and output areas for ventilation
-The number of horizontal partitions inside the enclosure if applicable
-The relative position of the equipment in relation to walls, ceiling and neighbor equipment (as presented in IEC 60890)

For the sake of reproducibility, the measurement of the total per phase and partial electrical contacts resistances, before and after the test, shall be registered in laboratory test report.

The values of the data mentioned above shall be clearly registered in the test report trough drawings and photos,

3.6 - Minimum input data to be registered in internal arc tests laboratory test reports

Equipment is approved during a test if the effects of the overpressures arising during the arc do not cause potential risks to persons in the neighborhood of the equipment.

The relevant aspects to consider are showed in the relevant product standard. IEC 62271-200 and IEC TR 61641 explain the concepts involved.

The curve overpressure x time is the main agent for the good or bad test result. The data affecting the test and the simulations results are

- the circulating electric current,
- the materials used in the conductor and insulating parts
- the geometry and spatial position of the conductors
- the volume of fluid inside the compartments
- The input and output areas for ventilation and devices to close it during the arc
- The areas for pressure relief after the arc
- The relative position of the equipment in relation to walls and ceiling

For the sake of reproducibility, the measurement of the internal overpressure along the test shall be registered in the laboratory test report. The values of the data mentioned above shall be clearly registered in the test report trough drawings and photos,

3.7 - Minimum input data to be registered in short-time withstand current and peak withstand current test report

The objective of the test is to verify the supportability to the effects of electrodynamical forces on insulators and conductors occurring during a short circuit without arc. The verification is done by visual inspection and measurement of the resistances per phase.

The data affecting the test and the simulations results are
-The circulating electric current,
-The materials used in the conductor and insulating parts.
-The mechanical resistances of the insulators to compression, traction and flexion

-The geometry and spatial position of the conductors

For the sake of reproducibility, the measurement of the total per phase and partial electrical contacts resistances, before and after the test, shall be registered in laboratory test report.

The values of the data mentioned above shall be clearly registered in the test report trough drawings and photos,

If visible permanent deformations are identified after the test, they shall be registered by photos and an estimate of the maximum permanent sag after the test.

4 Working procedures

4.1 General

When dealing with subjects relating to the use of simulations or calculations to replace real laboratory tests, in product standards, committees shall follow the provisions of this Guide, which is to be used in conjunction with the ISO/IEC Directives.

The status of the simulation or calculation methods, as well as the acceptable values of tolerances, shall be re-evaluated during the maintenance process.

4.2 Product publications

Committees developing product publications, dealing with subjects covered by this Guide, shall incorporate this Guide into their own publication by reference.

If necessary, they may specify, in their own publications, additional details relevant to their product area

5 Some examples of test results and input data which can be used as a calibration or a reference example to validate a simulation model

This example has the purpose to show how product standards may include examples relevant to the use and validation of simulations.

It relates to typical medium voltage switchgear. The detailed input data is showed in the Figure 1 (geometry) and Table 1 (conductors, currents and materials).

The results of the simulation for the temperature rise test are showed in Table 2. The results for the internal arc test are showed in Table 3. The results for the short-time withstand current and peak withstand current tests are showed in Table 4.

Note: The data marked with (*) in Table 1 is available but it was intentionally omitted by the author. In a real GUIDE issued by an International Standardization Body this data shall appear instead of (*).

Figure 1– Geometry input data for a test simulation on medium voltage switchgear. The numbers of the conductors are the same used in Tables 2 and 4

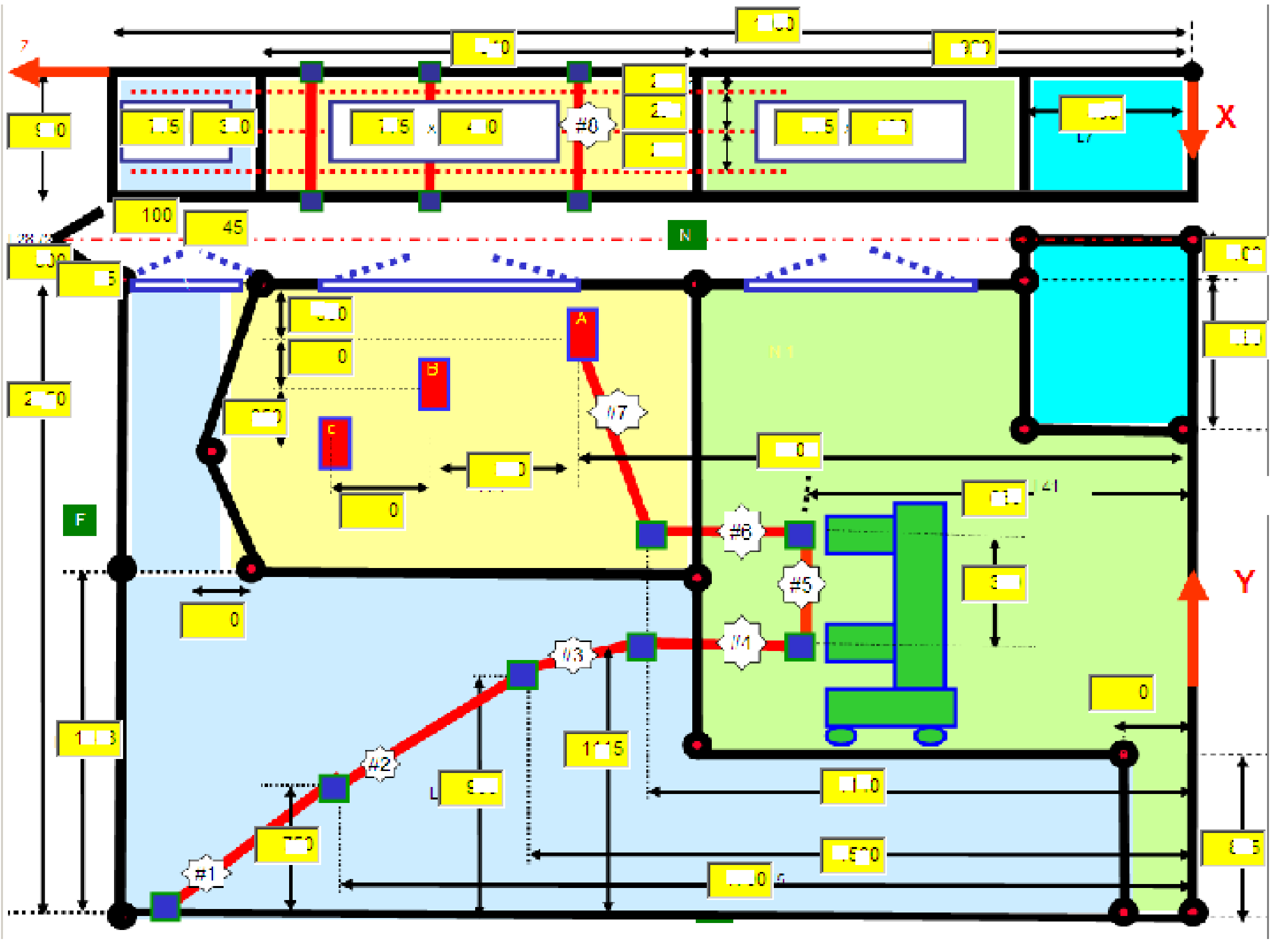

Table 1 – Input data for the simulation of temperature rise test, internal arc tests and short time current peak withstand tests

Rating	Value
Rated voltage (U_r) and number of phases	15,0 kV - 3Φ
Rated frequency (f_r)	60 Hz
Rated normal current (I_r)	(*) A rms
Rated short-time withstand current (I_k) and duration (s)	31,5 or 40,0 kA $_{rms}$ – 1s
Rated peak withstand current (I_p)	79 or 100 kA $_{cr}$
IAC (Internal Arc Classification)	IAC AFLR - 31,5 or 40,0 kA - 1,0s
Busbar dimensions and material	2 coppers bars (*) x (*) mm per phase
Circuit breaker contacts resistance	<=45 Ohms E-6
Total resistance per phase	<= 112 Ohms E-6
Inlet and outlet free ventilation area (cm2)	(*) cm2 x (*) cm2
Forced ventilation rated if any (m3/h)	No
Pressure relief free area (cm2)	(*) cm2
Absorbers or parts like grids working as absorbers	Yes with a free area (*) cm2

Table 2 – Temperature rise test and simulation results (K).

Point of the measurement	Test result (K)	Simulation result (K)
Connection at conductor # 1 (short circuit point)	47	42
Connection at the end of conductor # 3 (circuit breaker - low)	57	54
Connection at the end of conductor # 4 (circuit breaker-low)	64	66
Connection at the end of conductor # 5 (circuit breaker-high)	64	65
Connection at the end of conductor # 6 (circuit breaker-high)	52	53
Connection at end of conductor # 7 (top horizontal)	32	28
Enclosure door circuit breaker	5	
Fluid 50% height - cables compartment	not measured	13
Fluid 50% height - circuit breaker compartment	not measured	9
Fluid 50% height – bus-bars compartment	15	15

Table 3 – Internal arc test and simulation results (K).

Parameters	Test result	Simulation result
Symmetric or Asymmetric current	Asymmetric	
Arc voltage (V rms)	530	567
Maximum overpressure above 1 bar ΔP (%)	52	52
Overpressure duration (ms)	42	45
Integral Pressure curve along the time (bar*s*1000)	(*)	13
Time to 100% of overpressure peak ΔP (ms)	18	21
Time to 50% of overpressure peak ΔP (ms)	24~26	36

Table 4 – Short-time withstand current and peak withstand current test and simulation results

	Test result	Simulation result
Max. Mechanical stress σ_H (N/mm2)	Not measured	94
Max. Mechanical stress σ_T (N/mm2)	(*)	18
Max. mechanical stress $\sigma_H + \sigma_T$ (N/mm2)	(*)	111
Max. Force on the insulator in compression or tension (N)	(*)	8918
Max. Force on the insulator in flexion (N)	(*)	5711

.