VALIDATION OF TEST REPORTS ISSUED BY RECOGNIZED TESTING LABORATORIES

(With a view in switchgear, busways, ISO / IEC 17025 and the use of simulations to replace lab tests)

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1) INTRODUCTION, IMPACT OF IEC STANDARDS AND SOME TESTS

This article is the continuation of the ones in references [1, 4, 5, 6, 7] listed in the Annex A. Since 2007 I have been disseminating the idea that simulations and calculations can replace many of the actual tests done in testing laboratories. Frequently, when I try, by the first time, to convince someone that a laboratory test can be replaced by simulations the first questions are usually on how I can assure that these simulations are correct and how were them validated. These are normal questions with easy to prove answers.

The aim of this paper is to ask more or less the same questions for the validation of test reports issued by testing laboratories. Some questions and doubts I have are:

- Can we consider that a test report is validated when you cannot identify the characteristics of the equipment which was tested by photos, drawings and key information?

- Is it reasonable to accept a test report without knowing what was inside the closed metallic box only because it was issued by a recognized laboratory?

- What about test reports which do not have a written conclusion (passed / not passed) and are accepted for commercialization? Who has the responsibility to know if the results written there means "passed" or "not passed"?

Along the text, when I refer to technical standards I have in mind the IEC standards which are the more representative standards used in the worldwide market. When I use the terms simulations and calculations I am referring to methods which are not dependent of sophisticated or expensive software tools. The standards in references [8 to 13] contain good examples of relatively easy and proved methods.

I will use as examples three of the most expensive tests done in high power testing laboratories:

- Temperature rise tests
- Short time withstand current and peak withstand current (electrodynamical forces)
- Internal arc tests.

TEMPERATURE RISE TESTS are applicable from low to extra high-voltage equipment [5]. The equipment is installed in a room free of air drafts and the rated current is applied during a time sufficient to have stabilization of the temperatures of the measured points. The temperature rises measured shall not go beyond certain limits specified in the relevant standard.

The results are influenced by the circulating current, the type of materials, the contact resistances, the fluid temperature, the geometry of conductors, the net internal volume of the compartment and the existence or not of ventilation openings and systems [10]. The contact resistances are ventilation areas are key factors for the results. If this resistance is not registered in the test report the test is not reproducible. IEC standards request to measure only the total resistance per phase and not also the resistance of the switchgear per phase as seen from the terminals.

SHORT-TIME WITHSTAND CURRENT AND PEAK WITHSTAND CURRENT TESTS are done to verify the effect of the forces and high temperatures which are applied to insulators and conductors during a short circuit. The mechanical forces acting in the insulators (compression, traction and bending) and the mechanical stresses in the conductors can be calculated using the expressions showed in [5] and methods in references [11 to 13].

The forces shall remain below the limits specified by the insulator manufacturer otherwise the insulator can be destroyed. The mechanical stresses on the conductors shall be maintained below certain limits (for example 200 N/mm2 for copper) otherwise the busbar will suffer a permanent and visible bending. The results are affected by the short circuit circulating electric current, the materials involved, and the geometry of the conductors plus insulators system.

INTERNAL ARC TESTS are also applicable to high, medium and low voltage equipment [5]. The Idea is to create an internal arc for certain duration. The consequences of the overpressures provoked are observed. Some of the requirements for being approved in the tests are that the doors shall not open permitting hot gasses to go outside and the gasses ejected through the pressure relief parts shall not burn cotton indicators placed near the accessible parts which simulate the skin of a person in the neighborhood. Holes caused by the arc in the external walls are not permitted.

For AIS switchgear the main cause of failures during tests is the firing of the horizontal cotton indicators after reflections of the hot gasses in the ceiling. The main factors influencing the results are the voltage, the current, the net internal volume and the area and the actuating time of the pressure relief devices. Ventilation openings, good in the temperature rise tests, are an example of a potential path to permit the hot gasses to burn the cotton indicators and to fail in the test.

2) USE OF SIMULATIONS TO REPLACE SOME TESTS AND THEIR VALIDATION

I became an advocate of the idea of replacing tests by simulations after working 25 years doing tests and managing high power and high voltage testing laboratories and, after this, in 10 years developing and using testing simulation methods and tools.

Based in this double experience the opinions I present here intend to be neutral and do not try to exaggerate the potential of simulations. Between the extremes of to test everything as it was practiced in the 80´s and to simulate most of the tests as I imagine it will be done around 2025 there are good possibilities just now.

Here I leave a message to colleagues testing engineers. When I worked in the testing laboratories I did not have any idea on how to calculate the temperatures of the busbars and parts during a temperature rise test or the impact of the pressure relief device in the overpressure.
For example, I did not have any feeling of how much would influence a 100 or 200 cm^2 ventilation areas or the resistance of contacts of a circuit breaker in the results of the test.

If I could know I would have written, in the test reports I signed, much more information even if the standard do not request. If you know that a certain parameter is relevant you shall register this in the test report [15]. Certain tests are simply not reproducible because some easy and cheap registers and measurements are not requested in the standards. On several occasions, in my consultancy work for manufacturers, I requested to the laboratories to measure the curves of pressure during the arc and the lab said it could not do it because it is difficult and the standard does not request. There is nothing difficult in this measurement and many laboratories do it free. The same occurs in some cases with the measurement of the contact resistance of circuit breakers and switches in the temperature rise tests.

The test engineer of the near future will need to be skilled also in the use of simulations tools. Few test engineers even in the most recognized laboratories in the World have this perception.
It's time to learn to look further ahead in time and not only to the waiting time of the list to book tests. The waiting time to do a test is each time longer in most of the testing laboratories I know. The prices are increasing by a simple question of market (small availability ~higher price).

The **positive impacts of the replacement of laboratory tests by simulations** are:

- a much lower cost in the development of the product
- more complete information than obtained in the tests
- less dependency of the availability and high cost of tests in laboratories (prices are higher than could be mainly because there are few laboratories in the World)
- reproducibility and transparency about what was tested
- reduce environmental impacts by avoiding liberation of liquid and gaseous residues during tests

The **barriers for the growth of the use of simulations** are:

- the lack of an IEC standard with guidelines for the use of simulations and calculations including the processes of validation [read Reference 6 with a complete proposal]

- the lack of knowledge by many experts that simulations and calculations are, from a long time, successfully used and specified in IEC standards like IEC 60076-5 (Power transformers), IEC61439 (low voltage switchgear), IEC TR 60890 (switchgear temperature-rise calculations), IEC61117 and IEC 60865 (switchgear electrodynamical stresses calculations).
- The fact that the electrical sector has been living for decades hearing that "everything must be tested". Many experts never had contact with simulation tools ;
- the fact that some big international companies may consider that the use of simulations is a threat because it would make medium and small manufacturers more competitive
- the lack of perception that each time more users are accepting simulations and that this process is not reversible (belter to join it than to become less competitive after).

Simulations can be used in the daily life in different levels as:

A. To replace directly the laboratory test (not to do the test).
B. To extrapolate the results of a laboratory test already done in a certain equipment to another one of more or less similar design
C. To estimate partially the performance of an equipment when certain aspects can be simulated and others not.
D. As a tool for testing laboratories to understand the impact of the parameters that should be registered in the test report to make the test reproducible

Level A (total replacement)
In this level I include the temperature rise tests. Here I am telling about the complete replacement of the test by the simulation. To calculate the temperature rise in the same points requested in the tests it is not necessary to use complex CFD computational tools The validation of simulation is easy because we need just to compare the temperature rises in the test and in the simulation considering the data mentioned in Section 1 and in Ref. [6] .

Level B (extrapolation)
Here I include the short time current test, the already mentioned temperature rise test, and the aspect of the internal arc test related to the calculation of the overpressures. If you have the results of a test previously done it is not complicate to adjust the simulation model to give the same results of the test.

An example of possibility of extrapolation of results is the following. A temperature rise test was made at 2500 A in a switchgear of known dimensions formed by copper bars 2x(100x10)mm per phase The top and bottom ventilation areas are known and the electric resistance per phase seen from the terminals, of a fixed circuit breaker inside was 18 µΩ. We want to know the results if the same test was made with 2000A, the same ventilation area but with a non-fixed circuit breaker with a higher electric resistance 30 µΩ In the test done in the laboratory the temperature rise of the circuit breaker connections was 74K and the standard limit is 75K (passed).

In all the cases the validation of the simulation is done by direct comparison with the test results considering the data mentioned in Section 1 and in Ref. [6] . In the case of the overpressures of the internal arc test you need to request the laboratory to measure them because the standards do not request to measure it while simple to do. How much useful information has been lost over decades of tests by this reason? The same apply to the measurement of the resistances per phase seem from the terminals of circuit breakers and switches during temperature rise tests. The standard only request to measure the total resistance per phase and not also the resistance of the circuit breaker.

For the short time current test the ideal validation would be a comparison of forces and stresses but this is very complicated and expensive to do. Nevertheless the methods indicated in the IEC 61117 and IEC 60865 are used in the last 100 years to design substations busbars and also extremely high current busbars used in testing laboratories. So, to validate the simulation it is sufficient to compare with the results of the several calculated cases showed in these standards.

Level C (to estimate the performance of certain aspects but not all)
This is the case of internal arc tests where the overpressures and the burn through can be accurately simulated but the assessment of the reflections of hot gasses and particles cannot be proved because there are not laboratory measurements available (Figure 1)

Level D (as a tool for testing laboratories)
This is an excellent application for the users of laboratories. Several extrapolations and sensitivity analysis can be done at the moment of the test and even included in the test report adding an exceptional amount of information and value for future developments of the user. Laboratories can offer this service as a source of revenues.

3) VALIDATION OF TEST REPORTS ISSUED BY TESTING LABORATORIES

In reference [5] it is described how important are some measurements which are necessary but not requested in the standards like the overpressure curve for internal arc test and the circuit breaker or switch electric resistance during temperature rise tests. As they are not requested by the standard, rare testing laboratories expend time to do them although they are easy measurements. In [6] we list all the data that should be registered in the test report to assure that the test is reproducible.

I tried to better understand the reason of these deficiencies. The general rules used by testing laboratories related to the identification of the tested equipment and test practices are at the **ISO/IEC 17025** - General Requirements for the Competence of Testing and Calibration Laboratories. The clause 5.10 is of our special interest.

Reading the text we see that **all the principles of the good identification and what should be written in the test report are there** through sentences like:

- a description of the condition of and unambiguous identification of the item(s) tested..
- where relevant, to include a statement of compliance / non-compliance with requirements and/or specifications
- where appropriate and needed, opinions and interpretations of the test results

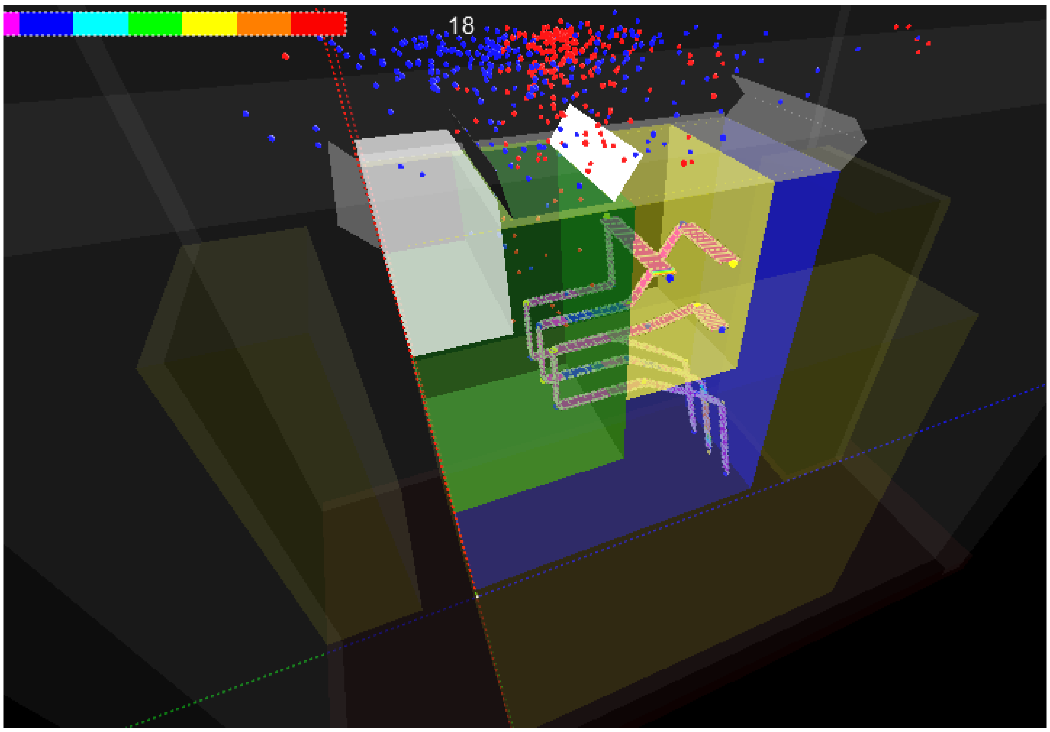
I could not find in ISO/IEC 17025 any indication to include, in the test reports, a sentence which is common to find in the first page of the laboratory test reports "The results apply only to the specific devices tested and are recorded …"

So, as the product standard does not require explicitly registering the important information already mentioned, the laboratory does not register them because they do not know they are important and include "apply only to the specific devices" the way is open to have commercialized products quite different of the tested products.

I am not saying that someone would use these standard deficiencies to prepare a circuit breaker with a lower contact resistance specifically for the temperature rise test or would close the ventilation openings during an internal arc test instead of using an automatic dispositive to close them.

Nevertheless the standards do not take into account that we do not live in the perfect World.

Figure 1 – Simulation of the probability of burning the cotton indicators



Although this is not related to the subject of our paper, I will use the opportunity to mention something that I already posted [7] in the forum named
[IEC The Electrotechnical Standards Group](http://www.linkedin.com/groups?gid=2725372&goback=%2Eanp_2725372_1336516744711_1)
http://www.linkedin.com/groups?gid=2725372&goback=%2Eanp_2725372_1336516744711_1

IEC standards are used all over the World. They are the published in the languages spoken in the developed countries and are the basis for the national standards of many other countries. The process of translation of the original IEC standard to the other languages takes something like 3 years. This creates a delay of knowledge acting as a commercial barrier.

If IEC standards were also issued in languages like Portuguese, Chinese and Arabic (Ref.7] they could be used directly as the national standard in other countries in the same moment of the IEC standard publication and not many years after.

Another point in the same approach is that the experts who prepare the standards are high level people with a good technical view of the matters but not necessarily sensitive to the non-technical consequences of the standard far from their countries. Although IEC is open to the participation and voting of all member countries, in the real life, the great majority of the experts acting in the working groups are big manufacturers and big users of developed countries only. The participation of small and medium manufacturers even from the developed countries is small.

So the fact is that few countries make the standards which will be used by many countries of different realities and the last ones will have, if so, a text available in their own language three or more years after. I have seen people dismissing the importance of this aspect by saying that it's easy to do translations. It is an example of lack of vision that occurs outside of developed countries.

So, here is **a suggestion to the IEC Management Board.:** To create a management rule fixing that all the product standards should contain a statement or clause, with some lines, more or less like: **"Expected influence of the publication in the market of non-developed and developing countries".**

This type of approach was used many years ago for declarations about EMC – Electromagnetic Compatibility and was a source of many improvements in IEC standards.

The author of this paper is Mr. Sergio Feitoza Costa. Sergio is a Brazilian electrical engineer and his CV and other details are at the link http://www.cognitor.com.br/en_home.htm

Sergio has a 30 years experience in high power, high voltage and materials testing, R&D services, electrical equipment and power systems specification, simulation and operation. For many years he was the manager of the main high power and high voltage testing laboratories in Brazil.

He is a developer of conceptual design of high power and high voltage testing laboratories and also a developer of software tools for the simulation and development of switchgear, busways and other equipment for substation

His experience includes international technical standardization management (former chairman of IEC Technical Committee 32 - Fuses). He is currently member of the CIGRE WG A3.24 International - Simulation and calculations in substation equipment and also member of IEC working group SC 17 C / WG31: Guidelines for extending the validity of tests in metal-enclosed switchgear.

He coordinates the Internet FORUM Switchgear (MV & LV): A proposal for an IEC Guide for testing simulation http://www.linkedin.com/groups/Switchgear-Proposal-IEC-Guide-on-4219744?goback=%2Eanp_4219744_1336519195833_1

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ANNEX A – REFERENCES

[1] SIMULATION, IEC STANDARDS AND TESTING LABORATORIES: JOINING PIECES FOR HIGHER QUALITY SUBSTATIONS EQUIPMENT

Author: Sergio Feitoza Costa
Paper PS1-06 - CIGRÈ International Technical Colloquium - Rio de Janeiro - September 2007

Free download http://www.cognitor.com.br/Artigo_Cigre_SergioFeitozaCosta_Cognitor.pdf

[2] SIMULATIONS AND CALCULATIONS AS VERIFICATION TOOLS FOR DESIGN AND PERFORMANCE OF HIGH-VOLTAGE EQUIPMENT

Co-authors: M. Kriegel, X. Zhu, M. Glinkowski, A. Grund, H.K. Kim, P. Robin-Jouan, L. Van der Sluis, R.P.P. Smeets, T. Uchii, H. Digard, D. Yoshida, **S. Feitoza Costa**

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[3] SIGNIFICANT PARAMETERS IN INTERNAL ARC SIMULATION AND TESTING

Co-authors: M. Kriegel, R. Smeets, N. Uzelac, R. Pater, M. Glinkowski, P. Vinson, **S. Feitoza Costa**, G. Pietsch, E. Dullni, Th. Reiher, L. van der Sluis, D. Yoshida, H.K. Kim, K. Y. Kweon, E. Fjeld,

CIGRE A3 Session - Paris 2009

[4] CELDAS, CUADROS, CANALIZACIONES Y OTROS EQUIPOS DE TRANSMISION Y DISTRIBUCION: FALTA ALGO EN LAS NORMAS IEC Y EN LAS ESPECIFICACIONES DE USUARIOS

Author: Sergio Feitoza Costa
Published in Spanish in the Revista RBE Energia – Edition Jan/Feb 2010 - page62 –

http://www.cognitor.com.br/RBE_Energia.zip
free download http://www.cognitor.com.br/Switchgear_Busbar_Standards_Review_Spanish.pdf

[5] VALIDATION OF SIMULATIONS OF ELECTRODYNAMICAL FORCES, TEMPERATURE-RISE AND INTERNAL ARC TESTS IN SWITCHGEAR (and main parts of a code to do them)

Author: Sergio Feitoza Costa
CIGRE Technical Seminar "Modeling and Testing of Transmission and Distribution Switchgear" March 24, 2010 Brisbane – Australia

free download http://www.cognitor.com.br/Validation_Simulations_English.pdf

[6] A "GUIDE" FOR THE USE OF CALCULATIONS AND SIMULATION OF LABORATORY TESTS FOR INCREASING THE COMPETITIVENESS OF THE ELECTRIC INDUSTRY
Author: Sergio Feitoza Costa
Published on January, 2012 at SETOR ELETRICO (Electrical Sector) - pages 110- 113

free download http://www.cognitor.com.br/Article_Competitivity_Eng_04102011.pdf

Note: This paper include a complete proposal for a new IEC Guide entitled " GUIDELINES FOR THE USE OF SIMULATIONS & CALCULATIONS TO REPLACE SOME TESTS SPECIFIED IN IEC STANDARDS"
http://www.cognitor.com.br/GUIDE_Simulations_v0_October2010.pdf

[7] POSTS AND PROPOSALS IN THE LINKEDIN GROUP COORDINATED BY SERGIO FEITOZA COSTA NAMED SWITCHGEAR: PROPOSAL FOR AN IEC GUIDE ON TESTING SIMULATION

Click in http://www.cognitor.com.br/Posts_upto_23_03_2012.html . Include among others the following themes (click to follow the link)

7.1 - About the objectives of the group.

7.2 - Complete draft of the proposed IEC Guide

7.3 - A suggestion to the IEC PRESIDENT and Management Board (suggestion to IEC to enable NWIPs not originated in National Committees like the above)

7.4 - Temperature rise tests concepts and calculations (slides from a Cognitor switchgear course)

7.5 - Suggestion for a new IEC " FUNDAMENTS OF HIGH POWER TESTS, internal arc, temperature rise and short time current and crest" (suggestion to IEC)

7.6 - Suggestion: IEC standards in Portuguese, Chinese, Arabic, … (suggestion to IEC)

7.7 - Free download of software Decidix developed by Sergio for the analysis of feasibility of projects

7.8 - IEC61439, IEC 62271-200 (measurement of internal air temperature and overpressures)

7.9 - Optimized cost solutions for switchgear design (paper)

7.10 - IEC 61439 Design Rules: why not to extend this from short circuit also to internal arc and temperature rise tests ?

7.11 - Where will arrive the hot particles and gasses emitted din the burnthrough of a switchgear ?: (info about simulations)

7.12 - Who may issue a reliable simulations report" ?: (info about simulations)

[8] IEC 61439-1 (2009) - Low-voltage switchgear and controlgear assemblies - Part 1: General rules

[9] IEC 61439-2 (2009) - Low-voltage switchgear and controlgear assemblies - Part 2: Power switchgear and controlgear assemblies

[10] IEC TR 60890 Ed. 1.0 b:1987, A method of temperature-rise assessment by extrapolation for partially type-tested assemblies (PTTA) of low-voltage switchgear and controlgear

[11] IEC 61117 – A method for assessing the short circuit withstand strength of partially type tested assemblies (PTTA)

[12] IEC 60865-1 Short-circuit currents - Calculation of effects - Part 1: Definitions and calculation methods.

[13] IEC 61865-2 – Short-circuit currents – Calculation of effects

[14] IEC TR 61641(2008) – Enclosed Low Voltage Switchgear Assemblies – Guide for testing under Conditions of Arcing due to Internal Fault.

[15] ISO/IEC 17025 - General requirements for the competence of testing and calibration laboratories

ADDITIONAL INFORMATION

DOWNLOAD OF SOME SLIDES OF A SWITCHGEAR COURSE APPLIED BY THE AUTHOR

http://www.cognitor.com.br/Part_of_Cognitor_Course.pdf

FREE DOWNLOAD OF SOFTWARE DECIDIX DEVELOPED FOR THE ANALYSIS OF FEASIBILITY OF PROJECTS

http://www.cognitor.com.br/c_Feasibily_Analysis.htm