A "GUIDE" FOR THE USE OF CALCULATIONS AND SIMULATION OF LABORATORY TESTS FOR INCREASING THE COMPETITIVENESS OF THE ELECTRIC INDUSTRY

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1) INTRODUCTION

What is better for countries that have an industry to manufacture equipment for substations, but does not have testing laboratories to test them? To use simulations or to remain complaining without doing anything. The organized use of calculations and simulation of tests is a possible and realistic solution and is increasingly accepted in the technical World.

A few years ago shopping in virtual stores on the Internet began growing. It was said that this was not going forward because you could not see the product and was unsafe. Today more and more people make purchases or banking transactions over the Internet. The products are cheaper in this way, shopping is faster and problems that occur are resolved as the regulations are enhanced by the experience of use.

In 2007 this author presented the paper "Simulation, IEC Standards and Testing Laboratories: Joining the higher quality pieces for high voltage equipment" in the "CIGRE International Technical Colloquium." Initial reactions to the idea of replacing laboratory tests by simulations were similar to those of virtual shops. I am convinced that the testing simulations will be in more or less ten years the reference and not the exception.

I say this with the experience of whom over 25 years, helped to design, to build, to operate and to manage the main testing laboratories in Brazil. For many years I have argued that tests cannot be replaced by simulations. I changed my mind after validating simulations and realize that many tests may be replaced and with advantages. There are international laboratories assessing the opportunities under this scenario.

Replace testing by calculations or simulations is not a new idea. It is applied for decades in standards such as IEC 60076 - Power Transformers (short-circuit tests) and IEC 61439 (low voltage switchgear), which since 2009 has replaced the IEC 60439 and eliminated the old terms TTA / PTTA. The wording now is "design verification" and not "type tested"

The IEC 61439 is the most advanced world standard in the use of innovative concepts. It takes a step forward in replacing tests the so called "design rules". The concept is that equipment which is similar to another one already tested, under the point of view of certain design rules do not need to be tested or even verified by simulations. The standard allows a formal replacement of testing and, under certain conditions, even calculations and simulations do not need to be done. The TTA / PTTA approach was replaced by something much broader.

Simulations are also used if the equipment exceeds the capacity of testing laboratories (eg 1100 kV circuit breakers). There is a work in progress in the IEC to extend the validity of the type tests in medium voltage switchgear.

To avoid performing tests within the rules of common sense saves resources of society and leads to lower cost products. Simulations are also a way to achieve competitiveness in the market especially in countries with low availability of testing laboratories. South American countries have much to gain from the simulations and with concepts such as IEC 61439.

In this region and in many others in the World most national technical standards are always lagged in time from the IEC standards. For example in the case of Brazil, it is usual to wait the publication of a certain IEC standard and 2 to 3 years after, to start to translate them as the corresponding national standard. The result is that when the “new” national standard is published the next revision of the IEC one is ready for use.

Most of the IEC standards were established decades ago under the vision of "everything must be tested." This has to do with the fact that the most frequent participants in the meetings to prepare the standards are the major international manufacturers. In the past they had the vision, and resources to build their own laboratories and to develop products, now already tested.

Small and medium manufacturers cannot invest dozens of million Euros to build a laboratory and so can be benefited and to become much more competitive and independent using alternatives like simulations and design rules. They are the key actors to make this to grow.

Access to laboratories in South America and in many other countries is the biggest barrier fpr the qualification of products. For example in Brazil a good laboratory structure to support the electrical industry was established in the 80´s. This worked well for about 20 years and then stagnated in terms of capacity. There are initiatives underway to increase laboratory capacity in Brazil but the results should take 3 to 4 years. In practice we have had a permanent economic growth in the last decade but we are today without commercial testing laboratories to provide services to manufacturers

Here comes the main theme of this article is to propose the elaboration and formalization of a technical standard which can serve as a guide for the use of testing simulations to minimize the lack of testing laboratories.

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

The path to the systematic use of simulations is through a "Guide" with a format similar to the “horizontal” standards which are developed by IEC. The text to follow is a complete suggestion for this guide that was prepared by the author of this paper and formally sent to the CB-3 (Electricity) of the Brazilian National Standards Association (COBEI) in April 2011.

For that matter to advance it is necessary the evaluation of the ABNT on if the subject is considered relevant to the Brazilian Standards. If it is considered relevant it is necessary to create a working group too prepare the draft standard. The proposal was sent with the support of more than 20 companies that want to participate in meetings of the working group. This set included 15 equipment manufacturers, mostly high and low voltage switchgear but also testing laboratories, certification bodies, utilities and users.

The full text proposal, which is also being sent as a suggestion to standardization committees in other countries, can be read in http://www.cognitor.com.br/GUIDE_Simulations_v0_October2010.pdf .A summary of the proposed guide is described below and suggestions for improvements are welcome.

2.1) PREFACE (of the Guide)

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.

Temperature rise tests simulations are relatively simple to perform and to validate. Even with low complexity methods it is possible to obtain calculated values near to the values obtained during the laboratory 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 and calculated in the simulations.

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 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 in the IEC technical standards and consequently not 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.

The objective of this Guide is to present guidelines for the systematization of the use of simulations and calculations which may be used to replace some laboratory tests in situations where the common sense shows it is reasonable to use it. It specifies the minimum measurements and photographic registers that shall be done and registered in test reports, during laboratory tests specified in product standards. The Guide also indicates typical values of acceptable tolerances for the calculated values when compared with the results of the laboratory test.

2.2) SCOPE (of the Guide)

This Guide presents Guidelines for the systematization of the use of simulations and calculations 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. 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.

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.

2.3) DEFINITIONS (of the Guide)

2.3.1 - 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%

2.3.2 - Product publication
Publication covering a specific product or group of related products

2.3.3 - 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.

2.3.4 - 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.

2.3.5 - 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 t the bottom , top and 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)

3.6 - Data to be registered in internal arc tests laboratory test reports

Equipment is approved in the 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.

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
- The measurement of the internal overpressure along the test shall be registered.

2.3.6 - 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
- The measurement of the total per phase and partial electrical contacts resistances, before and after the test, shall be registered in laboratory test report.
- 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.

2.4) WORKING PROCEDURES

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.

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

3) **FINAL COMMENTS**

This original idea was formally sent to the Brazilian National Standards Committee April 2011 with the support of more than 20 companies, mostly manufacturers of switchgear.

It is also being sent as a suggestion, other standardization bodies in countries in South America and other parts of the World.

The use of simulations to replace tests, especially for countries with a low availability of testing laboratories, is a possible and realistic solution.

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