TEST SIMULATION REPORT 071/2014

http://www.cognitor.com.br/TR_071_ENG_ValidationSwitchgear.pdf

TITLE	VALIDATION OF THE SOFTWARE SWITCHGEARDESIGN_307 FOR THE SIMULATION OF HIGH POWER TESTS (temperature rise, short time and crest current tests – electro dynamical forces / stresses and overpressures due to internal arc)
	Software ***Switchgear_Design*** ***_307***
REFERENCE STANDARDS	IEC 62271-200 (High voltage switchgear and controlgear - Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV IEC 61439 - Low-voltage switchgear and controlgear assemblies. (to be published) IEC TR 62271-307: High-voltage switchgear and controlgear - Part 307: Guidance for the extension of validity of type tests of AC metal-enclosed switchgear &controlgear for rated voltages > 1 kV & < 52 kV
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1. INTRODUCTION.

This report was prepared for the training course entitled ENGINEERING AND DESIGN CONCEPTS + software for SUBSTATIONS AND EQUIPMENT FOR SUBSTATIONS

Updates and supplements information from the book "Reference text for the courses SWITCHGEAR, BUSWAYS & ISOLATORS and SUBSTATIONS AND LINES EQUIPMENT" that can be downloaded freely in the site http://www.cognitor.com.br/Book_SE_SW_2013_ENG.pdf

In addition, aims to help users of the software SwitchgearDesign who need to do validations of their simulations. In this aspect, it is possibly a single document in the world in November 2014. The software permit to simulate some expensive laboratory tests like the temperature rise tests, short time current tests (electro dynamical forces) and internal arc tests.

It is not an academic tool. It is focused in solving problems of the daily life of an electrical equipment designer.

Sergio Feitoza Costa, author of this report, developed the SwitchgearDesign. Sergio has long experience in the design, operation and management of big size testing laboratories. Sergio has an international recognized experience with high power and high voltage testing, equipment and testing laboratories design, construction, operation and management. He is for a long time member of IEC and Cigrè working groups. Some time ago, he was the Chairman of IEC Technical Committee 32. He is a member of the working group WG 31 of IEC which is preparing the new IEC 62271-307 and also of the CIGRE working group that is publishing in 2014 the new CIGRE brochure "Tools for the simulation of internal arc effects in MV and HV switchgear ".
CV at http://www.cognitor.com.br/en_curriculum.htm

Software without a person well trained in the engineering concepts can be a source of problems, not a solution. Therefore, the software is free to use only for people who go through the training shown at http://www.cognitor.com.br/SoftwareES.htm .

The conditions of use are "usage is at your own risk" The author and Cognitor are not responsible for any result or use given to the results.

In this report, there are some parts of sheets of test reports made in testing laboratories. There are also pages of other publications, which are useful for validation purposes (Annex D).

The parts covered by black marks were intentional to avoid the identification of names.

Suggestions and proposals for new case studies for validation are always welcome when accompanied by good test reports. Good test reports, in this context, are the ones in which the equipment is properly identified and the test results shown. Good identification is as shown in this future technical standard entitled "Guidelines for the use of simulations and calculations to replace some tests specified in international standards ". Sergio Feitoza Costa prepared this document in 2010. Download site: http://www.cognitor.com.br/GUIDE_Simulations_v0_October2010.pdf

2. SOFTWARE VALIDATION REPORT.

This report includes the following information:

- Standard / guideline for applying simulations to replace some laboratory tests
- User defined requirements (input and output software).
- Short manual is just the section 7 of the book published in http://www.cognitor.com.br/Book_SE_SW_2013_ENG.pdf
- The validation method used and comparison between simulation and test results reports or calculations of IEC standards.
- The acceptance criteria of simulations and conclusions on whether the software is proper for the intended use.
- Operating system requirements and software requirements.
- Information about the software design, implementation, programming language, operating technician support, installation and removal

All methods and topics covered in this report were derived from efforts of Cognitor already registered and published in national and international references whose links to freely download are shown in Annex 1.

These references, published mainly in the period 2007 – 2014, include titles like:

- Book “Switch gear, busways & isolators and substations and lines equipment”
- "Guide" for the use of calculations and simulation of laboratory tests for increasing the competitiveness of the electric industry”
  Validation of simulations of electro dynamical forces, temperature-rise and internal arc tests in switchgear (& main parts of a code)
- Simulation, IEC standards and testing laboratories: joining the pieces for higher quality HV equipment”.
- Validation of test reports issued by recognized testing laboratories
- Aluminum x copper in switchgear design (with an idea for a new concept)

3. TECHNICAL STANDARD (GUIDE) FOR THE APPLICATION OF SIMULATION TO REPLACE SOME LABORATORY TESTS

The old concept that "everything must be laboratory tested" was replaced by the low-cost computing capabilities. Today the concept of "test everything" is defended only by a few who understand that they would lose with the widespread use of simulations. It is a short-term thinking. For example, electrical testing laboratories and certification companies can add to their experience in testing the great potential of simulations to produce profitable and useful services.

A testing laboratory tests that can demonstrate by comparison (validation) that simulations provide approximately the same results as the tests can add a good source of funds doing, in addition to the testing services, services using simulations. To build a large laboratory has a cost in the order of magnitude of fifty to one hundred million dollars and that is why the tests are expensive. As a private business is not an attractive investment and due to this reason there are few laboratories in the world.

Some of the major worldwide manufacturers have testing laboratories in their countries of origin. This is your differential. To develop their own products using many simulations combined with the evidence. They have well-prepared development technical teams. Outside their countries of origin, they do not develop nearly anything new. Only mount equipment without adding technology. The use of simulations allows medium and small manufacturers to become more competitive and they are really becoming better.

Using simulations of electrical testing is a realistic solution increasingly well accepted. To replace tests by calculations or simulations is not new idea. It is applied for decades in technical standards such as IEC 60076 - Power Transformers (short tests), IEC 61439 (low voltage switchgear) and the previous IEC 60439.

For example, IEC 61439 is possibly the most advanced world standard in the use of innovative concepts. It allows the substitution of certain tests by the use of simulations and, more than this, by the so called "design rules". The concept is that if an equipment is similar to another one already tested in laboratory and attend to certain rules you do not need to test it.

For medium voltage, switchgear there is a very important work, of the same nature, in progress in IEC. The working group WG 31 IEC / SC 17C is preparing new document IEC / TR 62271-307: High-voltage switchgear and controlgear - Part 307: Guidance for the extension of validity of tests of type AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and Including 52 kV. Sergio Feitoza is a member of the IEC working group preparing this standard, expected for publication in July 2015.

The way to speed up the systematic use of simulations is through the preparation of an IEC standard roughly with the text presented in the paragraphs.

Here we call this "future" standard of <u>SIMULATIONS APPLICATION GUIDE (Guide).</u>

You may download the full text prepared by Sergio Feitoza in the site http://www.cognitor.com.br/GUIDE_Simulations_v0_October2010.pdf

Since this guide does not yet exist and probably the major international manufacturers, which coordinate the technical committees of IEC, will not propose it, is an interesting action for many countries to establish a commission to prepare it in their National Standards Association. An example is in Colombia where it was implemented a government regulation that allows, under certain conditions, the use of calculations and simulations.

3.1) FOREWORD (of the Application Guide for Simulations)

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 as 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 may predict results of several type tests. In many cases, they enable to obtain more complete information than the information obtained in a real laboratory testing. Simulations are used in situations like:

(a) to avoid switchgear tests in equipment with characteristics near to another one already tested

(b) To avoid duplication of testing on product certification processes, when small changes are done to an already certified product.

(c) To replace SF6 by air in internal arc tests.

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

For temperature rise tests, the simulation to replace a test is relatively simple to perform and to validate. You need only to compare the results of simulations with measurements of temperature rise shown in the reports of laboratory tests.

For internal arcs tests in switchgear the task is more complex but possible. What is to be checked 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 but IEC´s standard do not request this easy measurement to be made and recorded in the test report.

A lot of useful information in the tests is lost due to this omission in the IEC standard.

It will published in 2014 the brochure CIGRE WG A3.24 "TOOLS FOR THE SIMULATION OF EFFECTS IN INTERNAL ARC MV AND HV SWITCHGEAR". This work began in 2009 and there are several case studies supported by laboratory tests allowing the validation of internal arc simulations.

In section B.4 of this important document of CIGRÈ, this SIMULATION APPLICATION GUIDE prepared Sergio appear in the "references"

[Feitoza2010]: S. Feitoza, "Guidelines for the use of simulations and calculations to replace some tests specified in international standards". COGNITOR Guide 2010.

For short-time withstand current and peak withstand current tests the objective is to verify the supportability to the effects of electro dynamical 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 main reference for validation in this case is the document IEC 61117: Method for Assessing the short-circuit withstand strength of partially type-tested assemblies (PTTA). There is no known way to do validation of simulations electrodynamic forces though laboratory test reports. By the same reason the IEC 61439 and IEC 62271-307 documents also reference IEC 61117.

The greatest difficulty in validating simulation methods of electrical testing is that some simple measurements are not specified in IEC standards, to be made during the laboratory tests. Reliable information for comparison between test results and simulation data is missing. Most laboratories do not perform measurements not asked in the technical standards, whether simple to do. However, some do when requested by the customer before.

The purpose of this Guide is to provide guidelines for the systematic use of simulations used to replace some laboratory tests in situations where common sense indicate to be reasonable to do it.

The guide present the parameters that shall be recorded in laboratory tests to allow the future use of simulations in the extrapolation of the test results.

The Guide also indicates the typical values of acceptable tolerances for the values calculated in comparison with the results obtained in the test report.

3.2) SCOPE AND CONTENT (of the Simulations Application Guide)

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.

<u>It is not an objective of this Guide to present calculation methods for testing simulation.</u>

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.

3.3) SOME DEFINITIONS (of the Simulations Application Guide)

3.3.1 – Temperature rise test (concept)

The equipment is installed in a place free of air drafts. The rated current is applied for a time sufficient to have the temperature stabilization of the measured points. The measured temperature rise should not go beyond certain limits specified in the technical standard.

The results are influenced by the current flowing, the type of materials, the contact resistances, the temperature of the fluid, the geometry of the conductors, net internal volume of the enclosure and the existence of partitions and ventilation openings. The contact resistance and ventilation areas are key factors in the results. The test is reproducible only if the major resistances are registered. It is necessary to measure not only the total resistance per phase but also the higher resistance like a switch, circuit breaker key or fuse as seen from its terminals

3.3.2 - Short-time withstand current and peak withstand current tests (concept)

These tests are made for checking the effect of the forces and high temperatures applied to the isolators and conductors during a short circuit. It is possible to calculate the mechanical forces acting on insulators (compression, tension and bending) and the mechanical stresses on the bus bar conductors using the expressions shown in [5] and references methods in Annex A and Annex B [14, 15, 16 , 22 and 23].

The forces must remain below the limits specified by the manufacturer of the insulator otherwise, it can be destroyed. The mechanical stresses in the conductors must remain below certain limits (of the order of 200-250 N / mm2 for copper according to the same reference above) otherwise the bars will suffer a permanent and visible deflection.

The results are affected by the short circuit current, the materials, and the geometry of the conductors, distances between phases and the types of insulators.

3.3.3 – Internal arc tests and overpressures (concept)

The idea is to create an arc along a certain time duration. The consequences of the overpressures are observed. Some of the requirements for passing in the test are the evidence that the doors will not open allowing hot gases and the gases expelled out through the pressure relief parties should not burn cotton indicators placed near the accessible parts that simulate the skin of a person in the vicinity. Holes on the outer walls, caused by the arc. are not allowed.

The equipment is approved in testing if the effects of overpressure caused by the arc does not lead to potential risks to people nearby.

Issues to consider and assessment methods are in IEC 62271-200 (medium voltage - Ref. 12) or IEC TR 61641 (low voltage - Ref. 21).

For air, insulated switchgear the main cause of failures during tests is the burning of the horizontal cotton indicators due to reflections of the hot gases in the ceiling.

The main factors that influence the results are the voltage, current, net internal volume, relief area and time of operation of the pressure relief devices.

Ventilation openings, good in temperature rise tests are an example of a potential way for the exit of the hot gases, burning cotton indicators.

3.3.4 – Validation of a simulation or calculation method or a laboratory test and tolerances.

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.

Table 1 – Tolerances between test results and simulation results

Type of test	Parameter to compare	Typical values of acceptable tolerance
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	Electrodynamic forces and mechanical stresses	5% to 15%

In section B.4 of the “Cigrè brochure” the above is mentioned in the “references”

[Feitoza2010]: S. Feitoza, "Guidelines for the use of simulations and calculations to replace some tests specified in international standards". COGNITOR Guide 2010.

3.3.5 – Product publication.

Publication covering a specific product or group of related products, for example IEC 62271-200 (medium voltage switchgear) or IEC 61439 (low voltage switchgear).

3.3.6 - 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 or more different occasions or two different test laboratories.

3.3.6 - Validation of a simulation or calculation method or a laboratory test.

Method of comparison between the results in a well-documented test report issued by a testing laboratory and the simulation results. The simulation method is acceptable when it is reproducible and shows a difference in relation to the results of laboratory tests unless an acceptable tolerance.

3.3.7 - 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 presented 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 above shall be clearly registered in the test report trough drawings and photos.

3.3.8 - 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 shown 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,

3.3.9 - 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 electrodynamic 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, photos and an estimate of the maximum permanent sag shall be registered.

3.4) PROCEDURES IN COMMITTEES WHICH PREPARE THE PRODUCT TECHNICAL STANDARDS IN THE NATIONAL STANDARDS ASSOCIATION WHICH IMPLEMENT THE GUIDE

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.

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

4. SOFTWARE SwitchgearDesign 307: USER REQUIREMENTS, INPUT and OUTPUT DATA, TRAINING AND MANUAL.

The software was made to help to develop equipment for substations (medium and low voltage) mainly panels, cubicles, busways, bus ducts, switches, isolators, and CCMs. It is a unique tool (search Internet and try to find any).

The software SwitchgearDesign_307 applies, inter alia, to products of IEC 62271, IEC 61439 and IEC 61641 standards and the relevant national standards. For a good use, you must have some experience of electrical design and have understood the concepts shown in the training.

The software allows simulating the following tests:
- Short time and crest withstand current (electrodynamic stress, mechanical stress).
- Temperature rise tests.
- Internal arc test (calculation of overpressure, burnthrough and supportability)
- Mapping of electric and magnetic fields (coming soon).

It is to be as simple as possible to enable manufacturers with limited access to testing laboratories, to perform virtual tests before going to the testing laboratory for getting a report type test used in the commercialization. The tool reduces the time and cost of product development. The main features are in Table 2.

Table 2 - Characteristics of SwitchgearDesign_307

Features	Version Course”
Simulation of temperature rise test	Yes
Simulation of electrodynamic forces	Yes
Simulation of internal arc test	Yes
3D geometry visualization	Yes
Mapping of magnetic field	Yes
Module MVSW1 (medium voltage)	Yes
Modules LVSW1 e LVSW2 (low voltage)	Yes
Module DUCT_1 (busways)	Yes
Module SWITCH (not validated)	Yes
Database and possibilities to modify, save and create new cases.	Comes with cases and you can create as many more as you wish.
Training “ In Company”	Yes

TRAINING “IN COMPANY”

To use the software is necessary to go through the training. Rather than learning to use the software, training tries to give to designers a better understanding of the design concepts and technical standards. Only the good understanding of engineering concepts enable to interpret correctly the results of the software.

Any software never will present results very different than expected intuitively by a designer with some experience. So if a unexpected result appears it is necessary to have the perception that there was an error in the input data

In the training program which is in some parts of the text displayed in the link http://www.cognitor.com.br/SoftwareEN.htm , all relevant information are explained and case studies are shown and discussed.

The requirements and input / output screens and data are shown in sections 3 and 7 of the book authored by Sergio named "SWITCHGEAR, BUSWAYS & ISOLATORS and SUBSTATIONS AND LINES EQUIPMENT" that can be downloaded freely in the site
http://www.cognitor.com.br/Book_SE_SW_2013_ENG.pdf"

The "manual" Software is the content of the pages presented in sessions 3 and 7 of the book and this report.

5. VALIDATION METHOD AND COMPARISON BETWEEN SIMULATION AND TEST RESULTS OR IEC STANDARDS.

For the SHORT-TIME WITHSTAND CURRENT AND PEAK WITHSTAND CURRENT TESTS (electrodynamic forces in insulators and mechanical stresses in the conductors) the validation of the simulations is done by comparing the simulation results with calculations of some cases presented in an IEC standard.

You cannot do otherwise as comparing measurements of forces and mechanical stresses with calculated values because such measurements are not performed in testing laboratories.

Laboratories do not measure the forces during the test, since it is very difficult to do and IEC standards do not require it. After the test, the physical state of the equipment is checked to verify if there are damages.

The validation used here will be to compare the software results with the results of the case studies presented in IEC 6117 (Method to evaluate the supportability to short circuits in low voltage switchgear) and IEC 60865-2 (Calculation of the effects of short circuits)

These IEC standards present a comprehensive methodology and complete calculations with all the input data and output results. The two cases used correspond to items 1 and 2 of Table 3 in this report.

For TEMPERATURE RISE TEST laboratory reports were used to compare test and simulation results (items 4, 5 and 6 of Table 3).

For INTERNAL ARC TESTS laboratory reports of laboratories with the necessary data are very rare. The reason is that the IEC standard 62271-200 and TR 61641 do not ask for measuring the pressure curves, which is the most important parameter.

In this report we used one laboratory test report (item 7 of Table 3) and two results that will be published in the 2014 CIGRE brochure (ref. [18] Annex B and Annex E). The cases are in items 8 and 9 of Table 3.

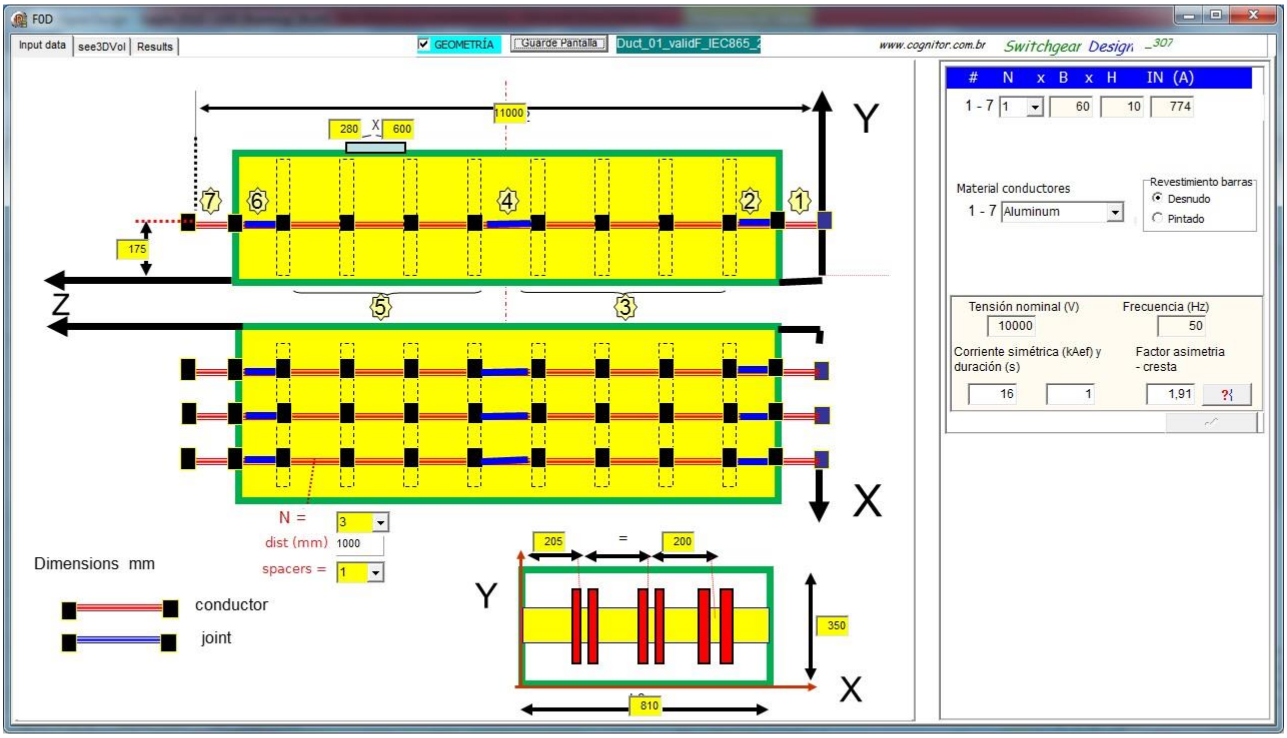
In Table 3, there are references of test reports used. Are also indicated the figures (software screens) showing the input data used in the simulation as well as the numbers of tables that show the comparison of the results obtained in the test and simulation.

Table 3 – Test reports used for validation of the methodology and software

	Test	Type of equipment (software screen) Case in the software database	Test report	Comments	FIGURES with inputs and simulation results	TABLE with the comparison tests x simulation
1	Short-time withstand current and peak withstand current	Duct_1 Duct_01_validF_IEC865_2 Page 11	Calculation in IEC 60865-2 (1994) Pages 11-17	Complete input data in IEC 865 Annex C	Figure 1	Table 4
2	Short-time withstand current and peak withstand current	Duct_1 Duct_01_validF_IEC865_2 Page 19	Calculation in IEC 60865-2 (1994) Pages 19-27	Complete input data in IEC 865 Annex C	Figure 2 Page 355 - 356 book Sergio (Seccion7)	Table 5 Page 357 book Sergio (Seccion7)
3	Short-time withstand current and peak withstand current	LVSW-2 LVSW2_01_M_R19901	Test report 19901/009-C (Annex D)	Equipment approved in lab test	Figure 3	Table 6
4	Temperature rise	LVSW-1 LVSW1_01_M_R67752	Test report 67752 (Annex D)	Circuit breaker 25 μΩ 768 w	Figure 4	Table 7
5	Temperature rise	MVSW_1 MVSW1_02_M_R65111	Test report 65111 (Annex D)	Circuit breaker 54 μΩ	Figure 5	Table 8
6	Temperature rise	Duct_1 Duct_03_3x150x10_R67131	Test report 67131 (Annex D)	Connection joint 7 μΩ	Figure 6	Table 9
7	Internal arc	MVSW_1 MVSW1_01_M_08-050	Test report 08-050 (Annex D)	Complete data with pressure curve	Figure 7	Table 10
8	Internal arc	MVSW_1 MVSW1_02_caseD_Cigre	CASE D Brochure Cigrè (Annex E)	Complete data with pressure curve	Figure 8	Table 11
9	Internal arc	MVSW_1 MVSW1_02_caseC_Cigre	CASE C Brochure Cigrè (Annex E)	Complete data with pressure curve	Figure 9	Table 12
10	Internal arc	MVSW_1 MVSW1_02_caseG_Cigre	CASO G Brochure Cigrè (Annex E)	Complete data with pressure curve	Figure 10	Table 11
11	Internal arc	MVSW_1 AbsorberPaper2013	Paper Absorber		Figure 11	Table 12

	Test	Type of equipment (software screen) Case in the software database	Test report	Comments	FIGURES with inputs and simulation results	TABLE with the comparison tests x simulation
12	Internal arc	ACI_1 ACI_1_ET651Duplex	CELDA ET651	Duplex Annex G	Figure 12	Table 13
13	Temperature rise	ACI_1 ACI_1_ET651Duplex	CELDA ET651	Duplex Annex G	Figure 13	Table 14
14	Temperature rise	ACI_2 ACI_1_ET651Triplex	CELDA ET651	Triplex Annex G	Figure 14	Table 15
15	Temperature rise	ACI_3	ACI_3_Breakers		Figure 15	Table 16
16	Temperature rise	ACI_4	ACI_3_Breakers		Figure 16	Table 17

Figure 1 – Duct1 – Short-time withstand current and peak withstand current IEC 865-2 –
Example1 - pages 11-17 – Duct_01_validF_IEC865_2
1 a – Input data



1 b – Results

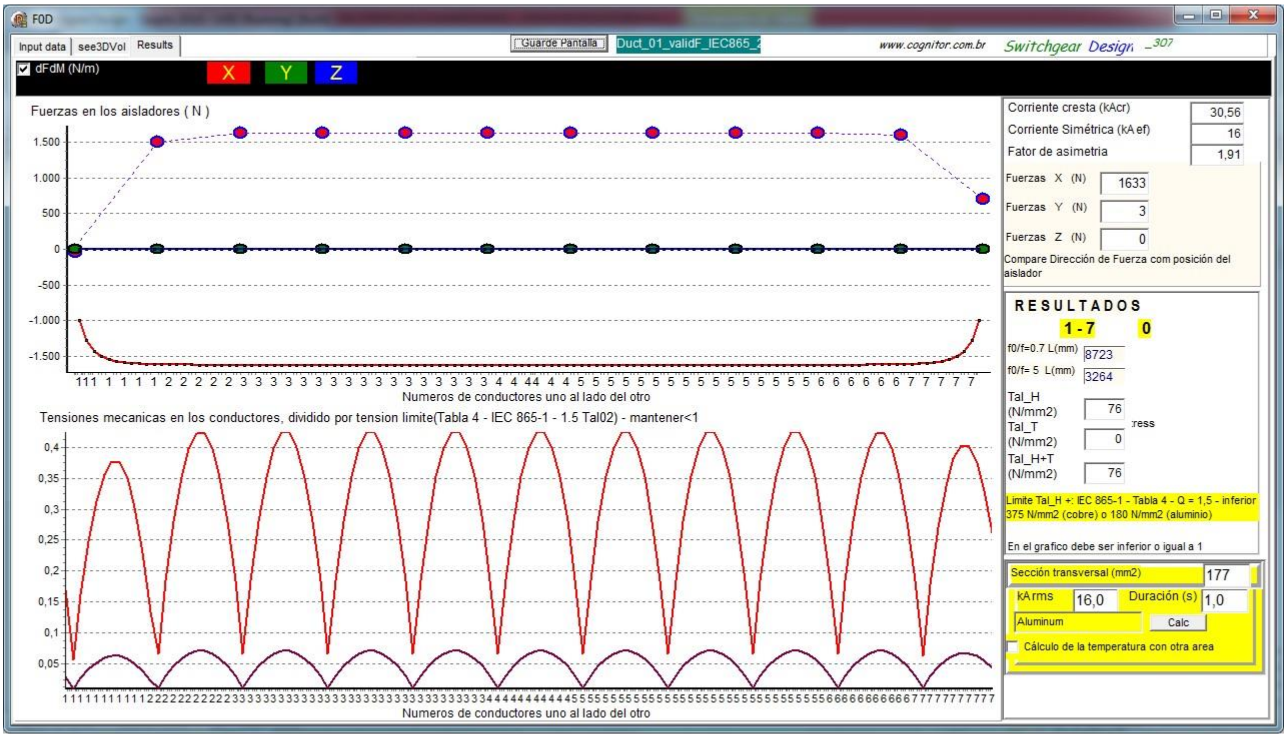
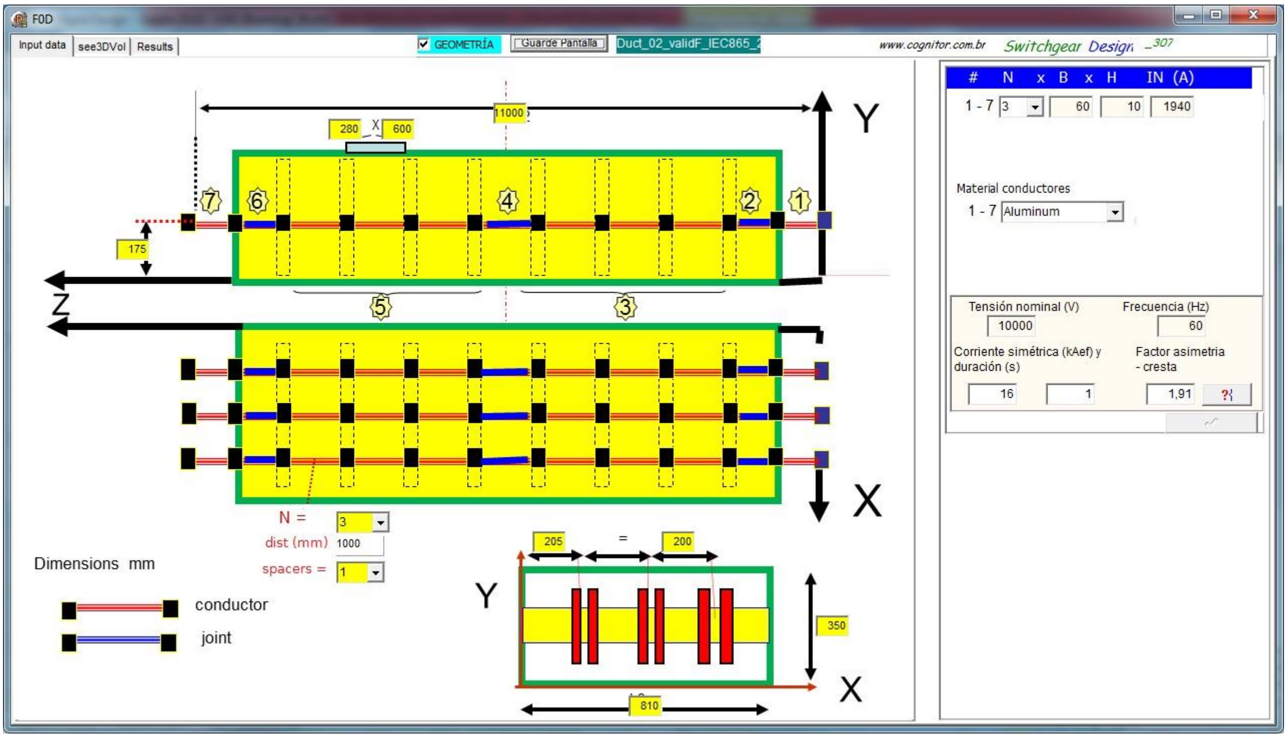


Table 4 - Duct1 – Short-time withstand current and peak withstand current
Case study – IEC 865-2 – Example 1 – pages .11-17 (Annex C)
COMPARISON BETWEEN TEST AND SIMULATION RESULTS IN IEC 865-2 Input data and results graph in Figure 1 Nomenclature of the data presented in Section 7 of the book

Parameter	Result in IEC standard (pages in Annex C)	Simulation results with software SwitchgearDesign	Difference
Max. Mechanical Stress σH (N/mm2)	73,3	76,0	3,5 %
Max. Mechanical Stress σT (N/mm2)	Do not apply	Do not apply	-
Total Max. Mechanical Stress σH + σT (N/mm2)	73,3	76,0	3,5 %
Max Force in the insulator in phase BB (central) in compression or tension (N)	Do not calculated	3	-
Max Force in the insulator in phase BB (central) in) flexure (N)	1606	1611	0,3 %

Figure 2 – Duct1 – Short-time withstand current and peak withstand current – IEC 865-2 –
Example 2 - pages 19-27
2 a – Input data



2 b – Results

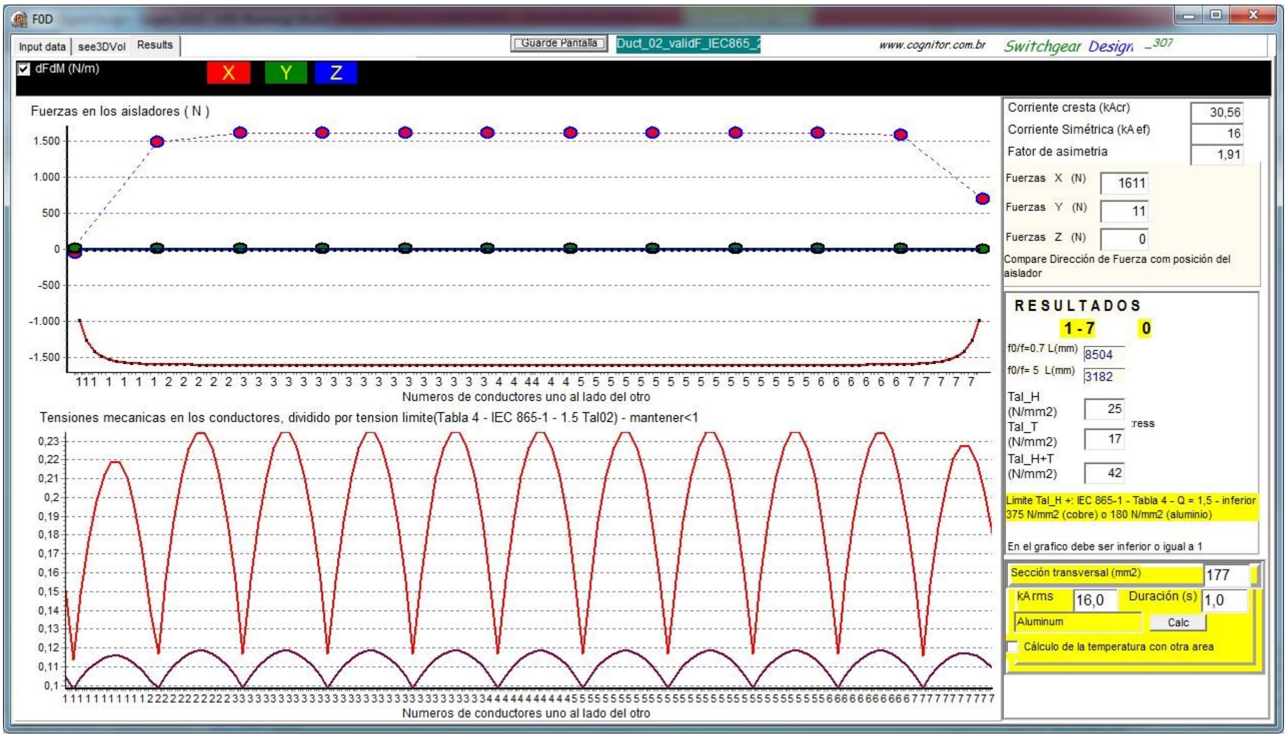
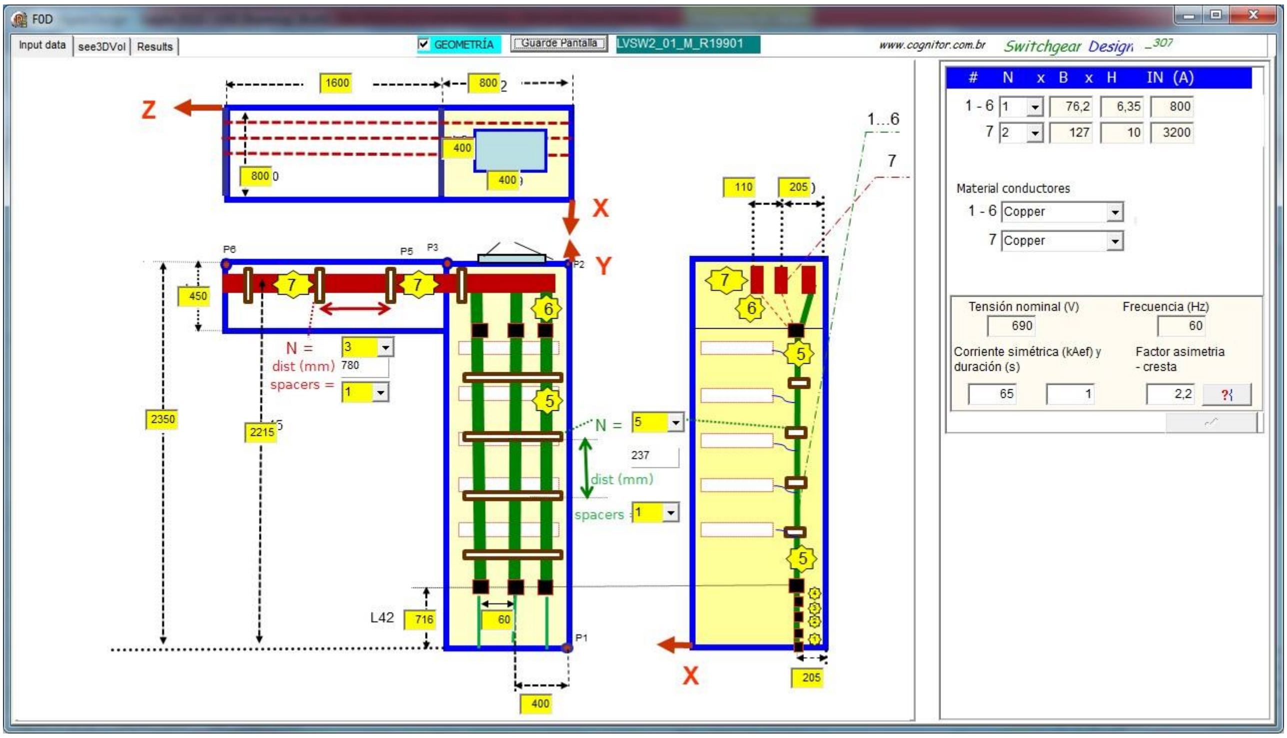


Table 5 - Duct1 – Short-time withstand current and peak withstand current
Case study – IEC 865-2 – Example 2 – pages .19-27 (Annex C)
COMPARISON BETWEEN TEST AND SIMULATION RESULTS IN IEC 865-2 Input data and results graph in Figure 2 Nomenclature of the data presented in Section 7 of the book

Parameter	Result in IEC standard (pages in Annex C)	Simulation results with software SwitchgearDesign	Difference
Max. Mechanical Stress σH (N/mm2)	24,7	25,0	1,2 %
Max. Mechanical Stress σT (N/mm2)	16,1	17,0	0,6 %
Total Max. Mechanical Stress σH + σT (N/mm2)	40,8	42,0	0,5 %
Max Force in the insulator in phase BB (central) in compression or tension (N)	Not calculated	11	-
Max Force in the insulator in phase BB (central) in) flexure (N)	1606	1611	0,3 %

Figure 3 – LVSW2 – Short-time withstand current and peak withstand current		
Example 2 - pages 19-27 -	Test report 19901/9-C	(Annex C)
3 a – Input data	LVSW2_01_M_R19901	



3 b – Results

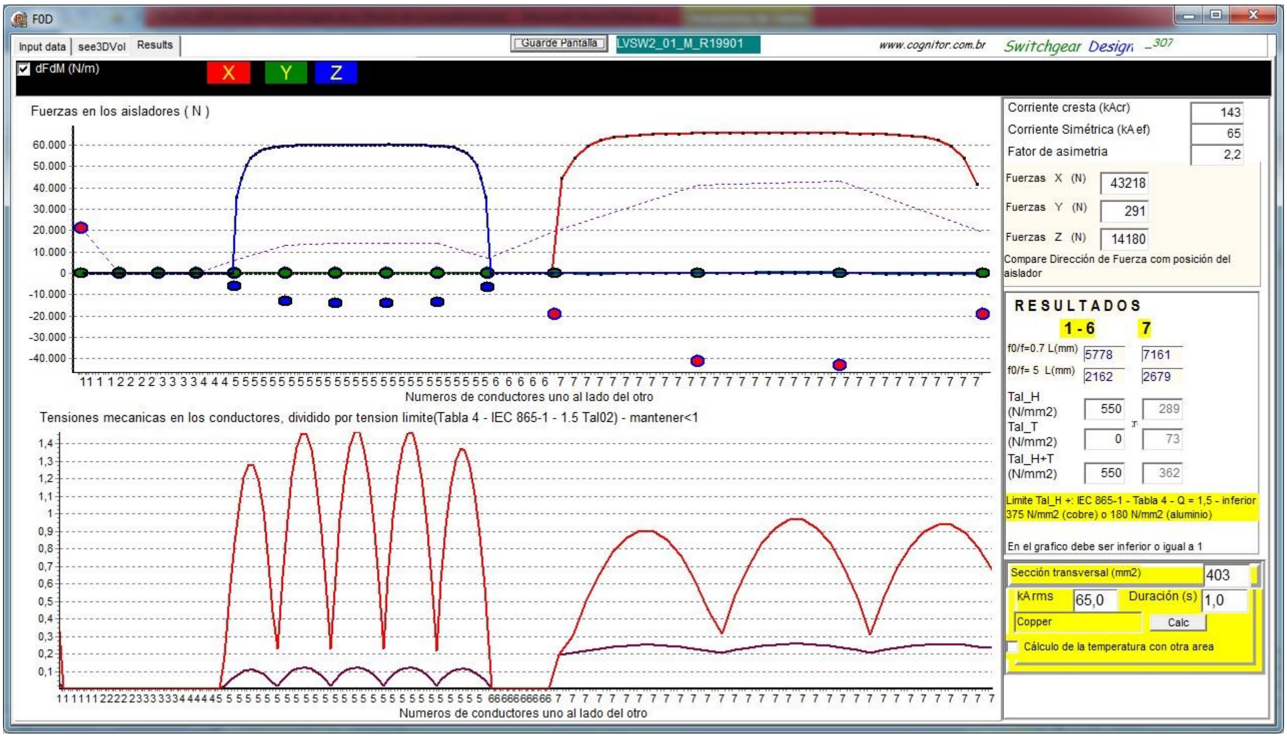
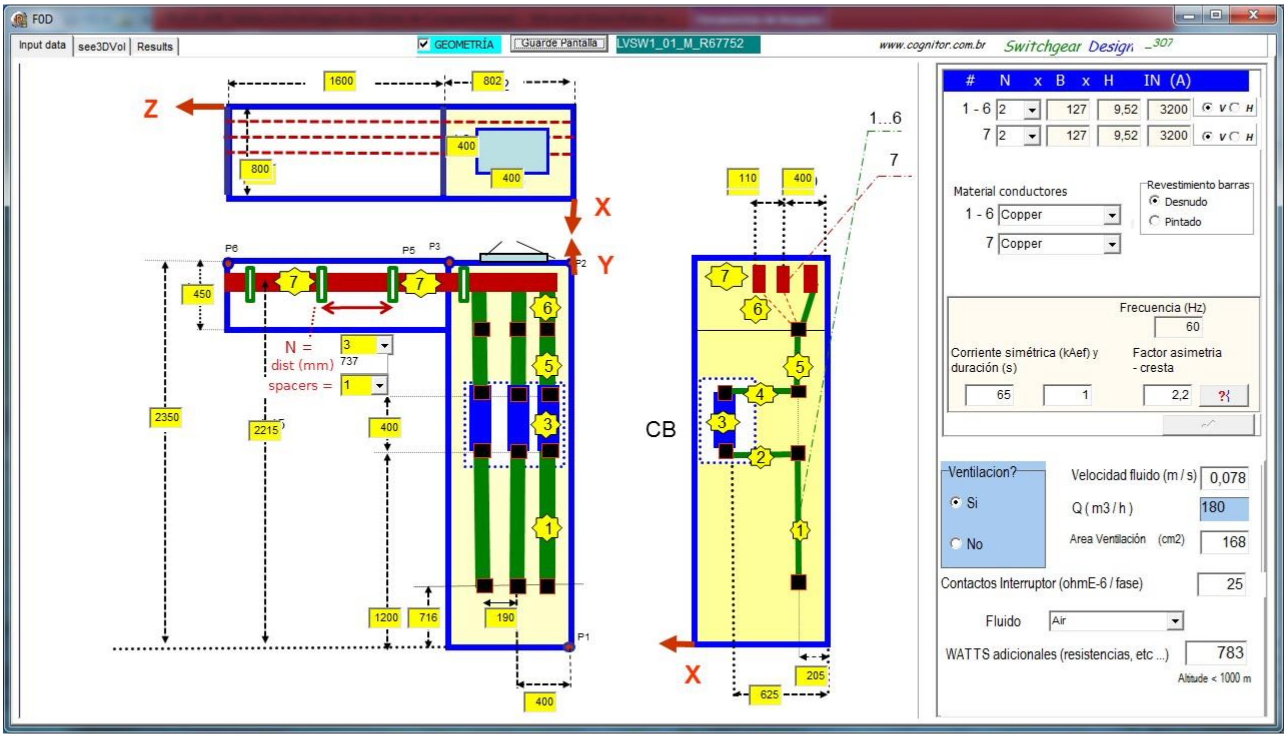


Table 6 - LVSW2 – Short-time withstand current and peak withstand current
Tested in laboratory - Test report 19901/9- (Annex C)
THIS CASE IS NOT INCLUDED IN IEC STANDARD AND STRENGTH AND STRESS MEASUREMENTS ARE NOT MEASURED IN LABORATORY Input data and results graph in Figure 3 Nomenclature of the data presented in Section 7 of the book

Parameter	Result in IEC standard (pages in Annex C)	Simulation results with software SwitchgearDesign	Difference
Max. Mechanical Stress σH (N/mm2)	Visual inspection	550 (*)	-
Max. Mechanical Stress σT (N/mm2)	Visual inspection	Not applicable	-
Total Max. Mechanical Stress σH + σT (N/mm2)	Visual inspection	550 (*)	-
Max Force in the insulator in phase BB (central) in compression or tension (N)	Visual inspection	14180 (*)	-
Max Force in the insulator in phase BB (central) in) flexure (N)	Visual inspection	Not applicable	-

(*) Values of interest are in conductors 1-6 - less resistant. Perceive that the limit usually used is 375 N / mm 2 = 1.5 x 250 N / mm2, but in this case passed the test and the value was 550 N / mm2 = 2.2 x 250 N / mm2

Figure 4 – LVSW1 – Temperature rise test		
In laboratory -	Test report 67752	(Annex D)
4 a – Input data		



4 b – Results

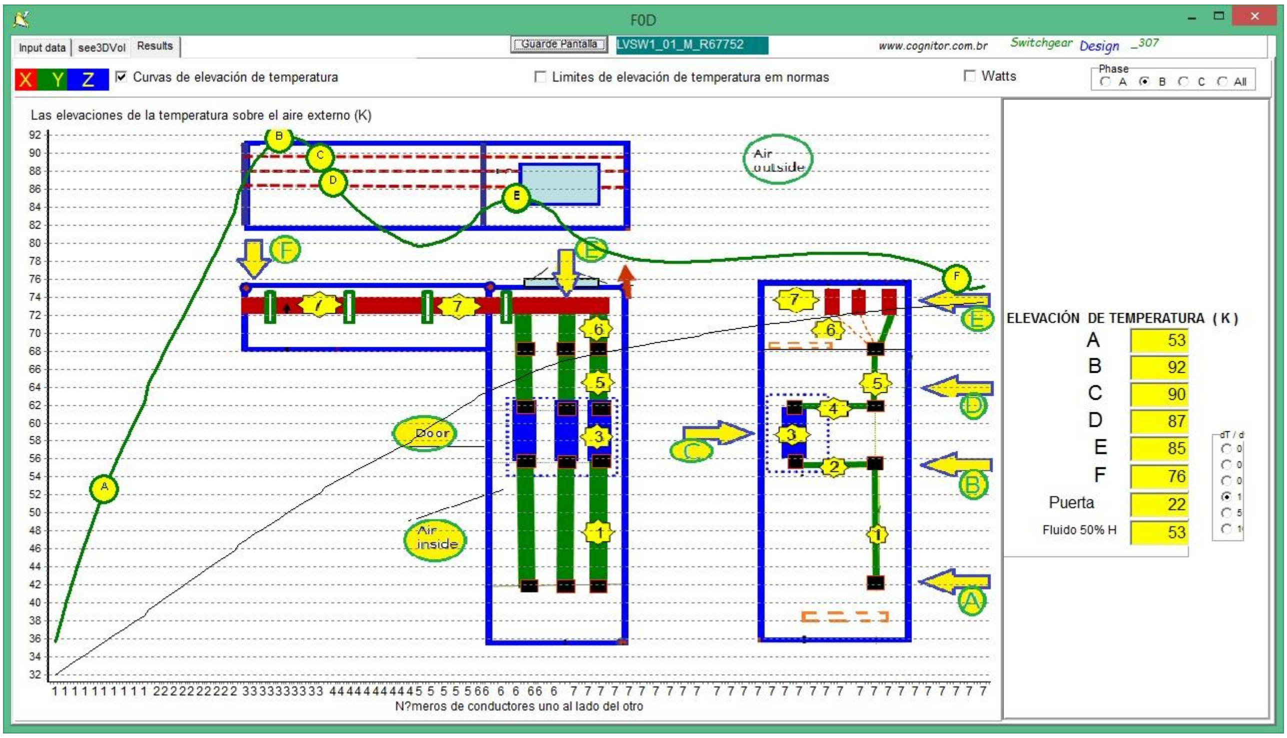


Table 7 –	LVSW1 –	Temperature rise test
Tested in laboratory -	Test report 67752	(Annex D)

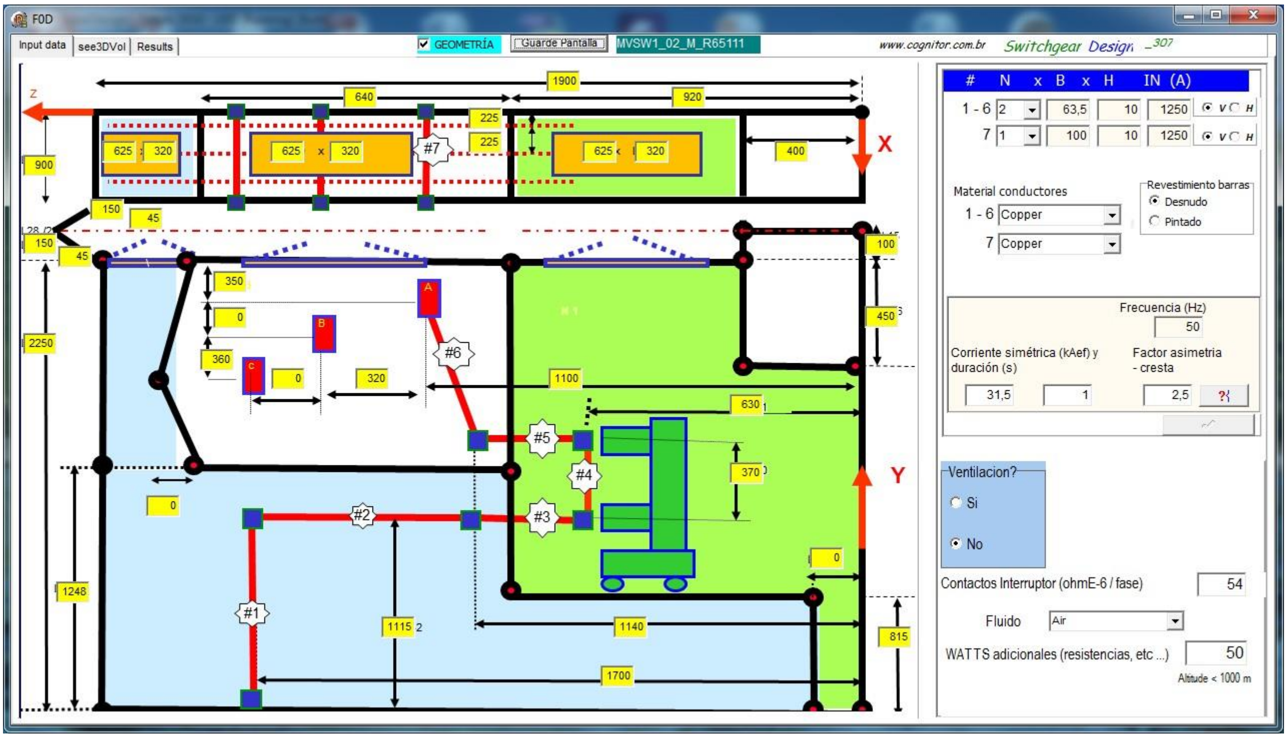
Input data and results graph in Figure 4
Nomenclature of the data presented in Section 7 of the book

Bare bus bar
With ventilation openings – 180 m3/h air flux corresponding to an average air speed of 0,078 m/s = 180 / (0,8x0,8) , effective area for the air input 168 cm2 Additional thermal load 783 W (to be added to bus bar resistances and connections and contacts)
Circuit breaker resistance as seen from the terminals – 25 μΩ per phase (768 W)

Measuring point	Test temperature rise (K)	Simulation (K)	Difference
A - Terminals for the connection to external conductors	53	53	< 5 %
B – C – D – connection between bars and circuit breaker (**)	78 al 89	87 al 92	< 5 %
E – Connection between the horizontal and vertical bars	76	85	< 8 %
F – Short circuit point	46 (***)	76	Thermocouple?
Door	8 (*)	<9	< 12,5%
Internal air	32 (*)	36 al 70	(*)

(*) The position where it was measured in the test is not indicated - no pictures - and the value can change greatly with position. In the simulation, the bottom has 36K and ceiling is 70 K. For the average height is about 50K.
(**) Critical point in testing
(***) possibly the thermocouple was not properly secured. See temperature point E - same bar

Figure 5	– MVSW1 –	Temperature rise test
In laboratory	- Test report 65111	(Annex D)
	5 a – Input data	



5 b – Result

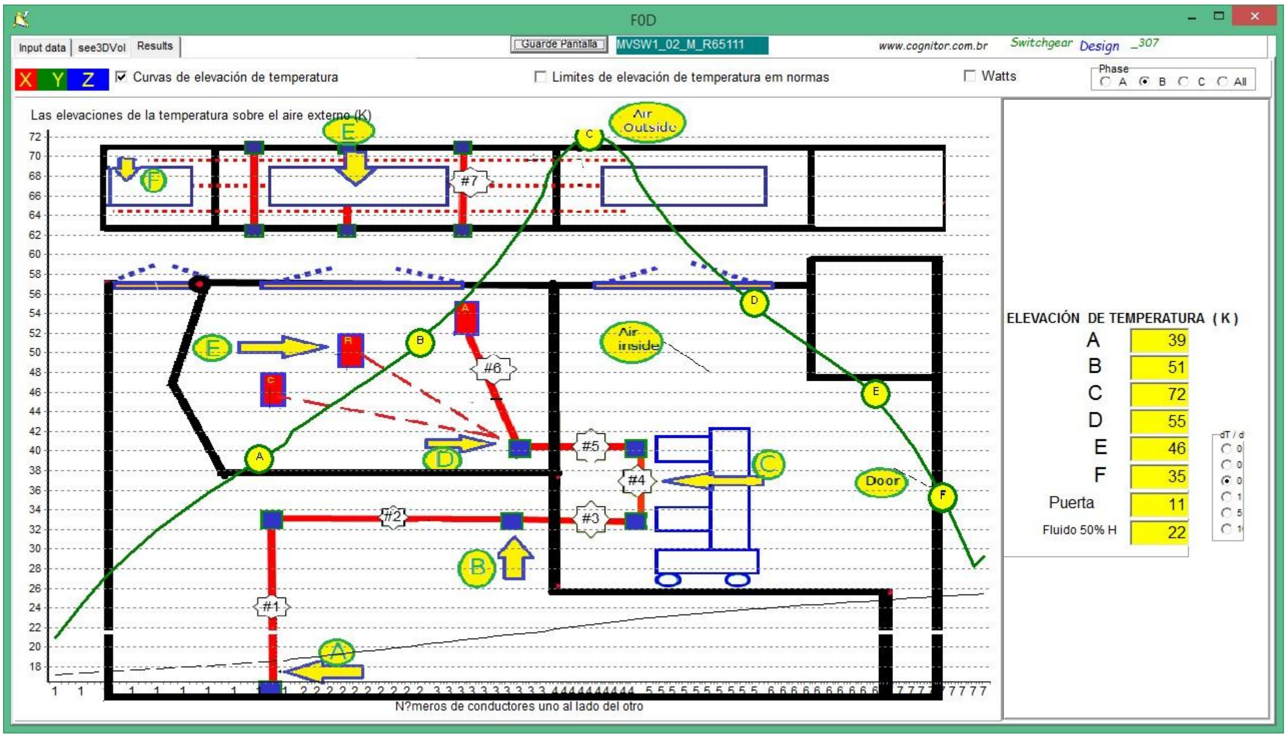
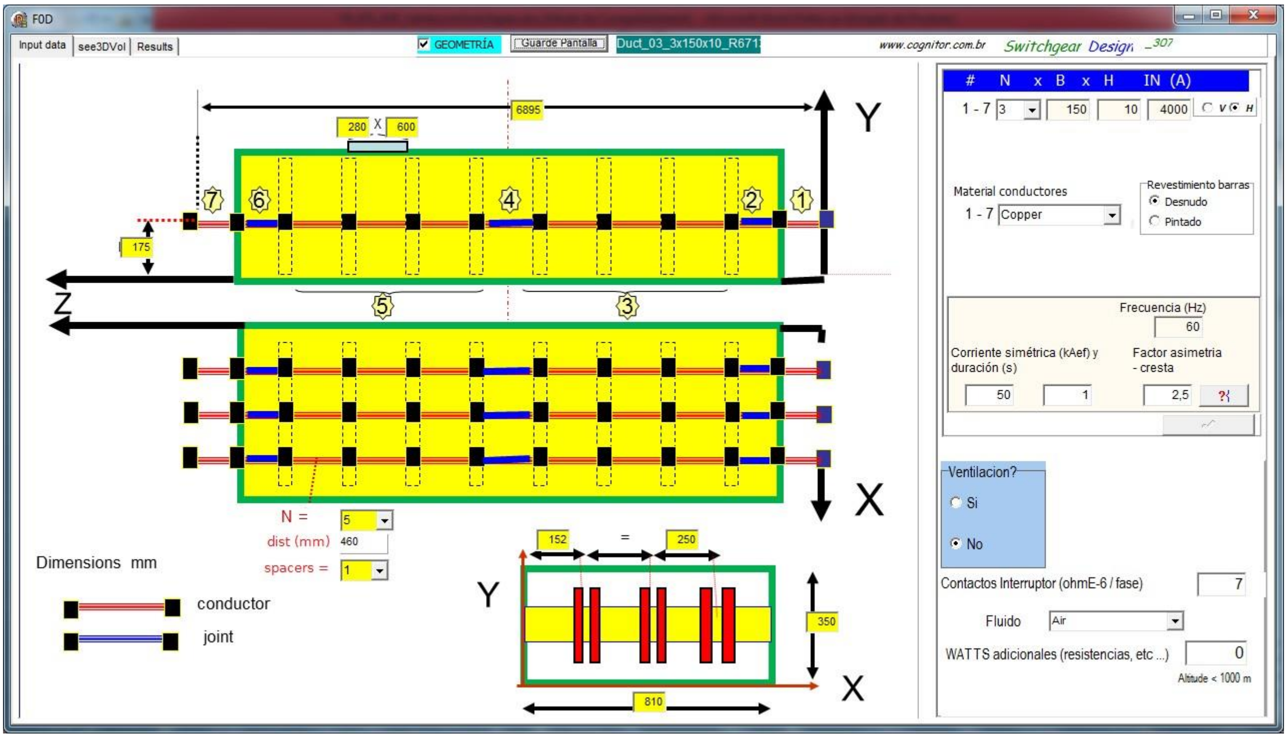


Table 8 – MVSW1 – Temperature rise test
Tested in laboratory - Test report 65111 (Annex D in this report)
Input data and results graph in Figure 5 Nomenclature of the data presented in Section 7 of the book Bare bus bar Without ventilation openings Circuit breaker resistance as seen from the terminals – 54 μΩ per phase

Measuring point	Test temperature rise (K)	Simulation (K)	Difference
A - Terminals for the connection to external conductors	39	39	< 5 %
B – C – D – connection between bars and circuit breaker (**)	56 al-72	51 al 72	< 5 %
E – Connection between the horizontal and vertical bars	44	45	< 5 %
F – Short circuit point	34	35	< 5 %
Door	12 (*)	11	< 15 %
Internal air	Not measured	13 al 26	(***)

(*) The position where it was measured in the test is not indicated - no pictures - and the value can change greatly with position.
(**) Critical point in testing
(***) in the simulation, the bottom has 13K and ceiling is 26 K. For the average height is about 20K.

Figure 6 DUCT1 Temperature rise test
In laboratory - Test report 67131 (Annex D)
6 a – Input data Duct_03_3x150x10_R67131



6 b – Results Duct_03_3x150x10_R67131

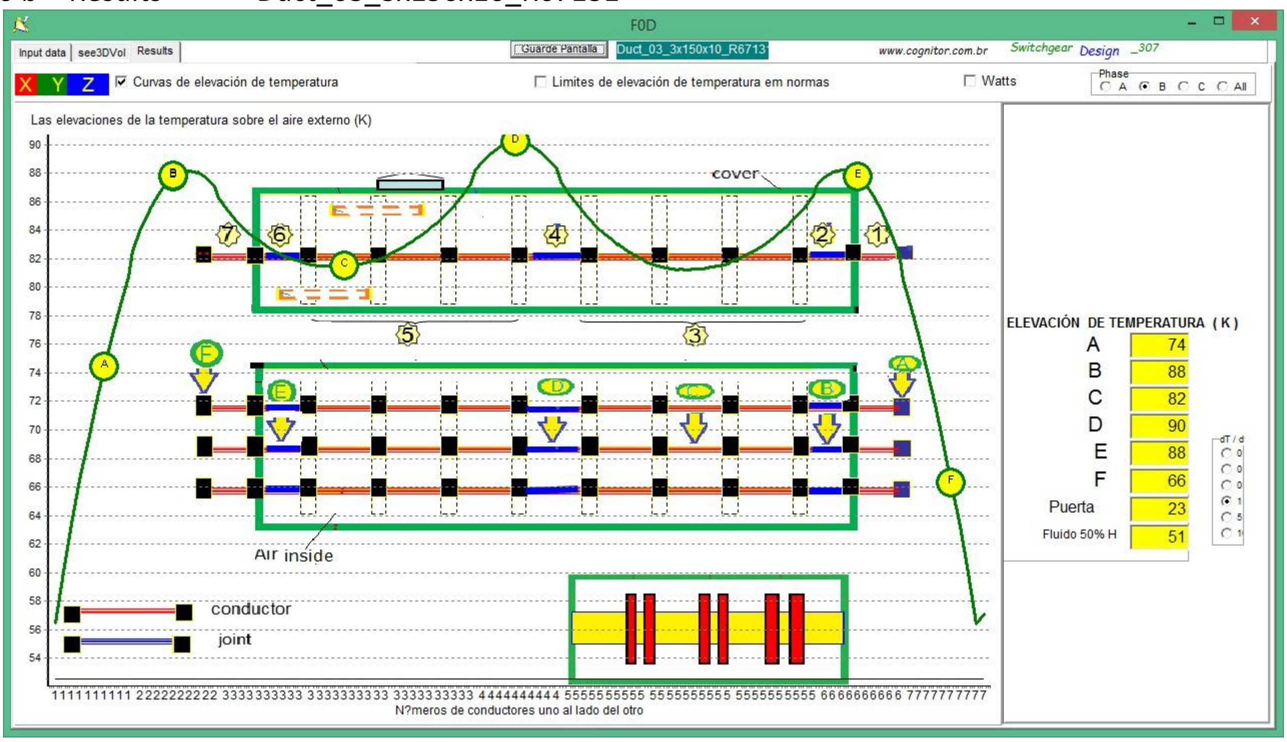
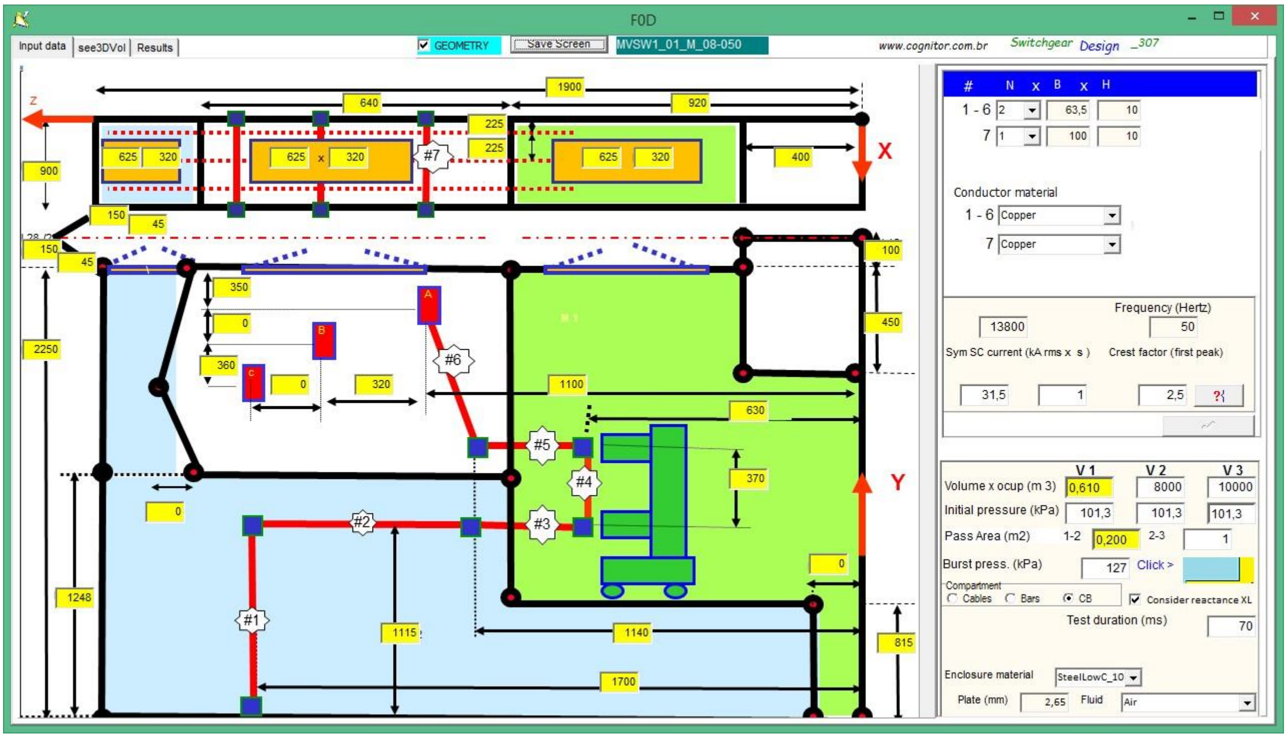


TABLE 9 DUCT1 TEMPERATURE RISE TEST
Tested in laboratory - Test report 67131 (Annex D)
Input data and results graph in Figure 6 Nomenclature of the data presented in Section 7 of the book Bare bus bar Without ventilation openings Connection / joint resistance 7 µΩ

Measuring point	Test temperature rise (K)	Simulation (K)	Difference
A - Terminals for the connection to external conductors	72,4	74	< 5 %
B – Conductor # 2	Not measured	88	-
C – Conductor #3	83,9	82	< 5 %
D – Conductor #4 (** connection)	84,5	90	< 10 %
E – Conductor # 6	Not measured	88	-
F – #7 – Short circuit point	66,6	66	< 5 %
Side of the enclosure	30 (*)	22	(*)
Internal air (50% H)	Not measured	51	-

(*) The position where it was measured in the test is not indicated - no pictures - and the value can change greatly with position. (From 9 to 51/2 = 25 K)
(*) Critical point in testing

Figure 7 – MVSW1 – Internal arc test		
In laboratory -	Test report 08-050	(Annex D)
7 a – Input data	MVSW1_01_M_08-050	



7 b – Result MVSW1_01_M_08-050

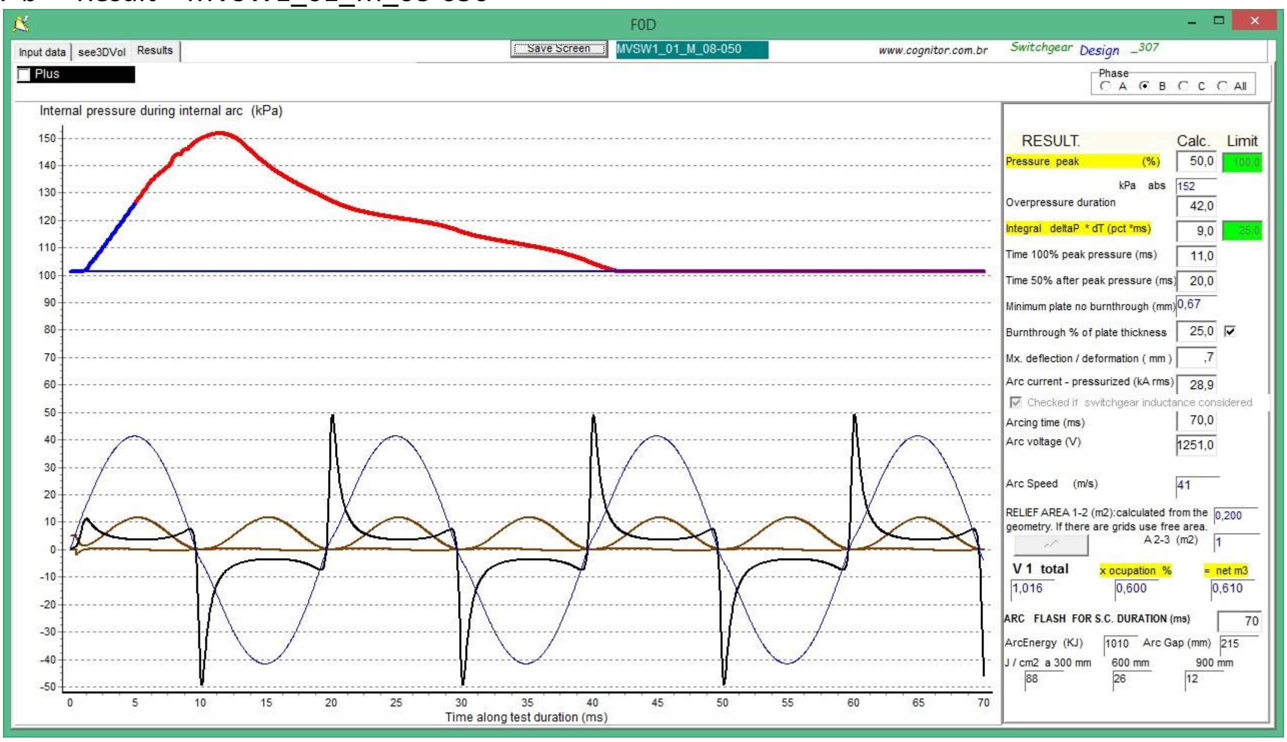
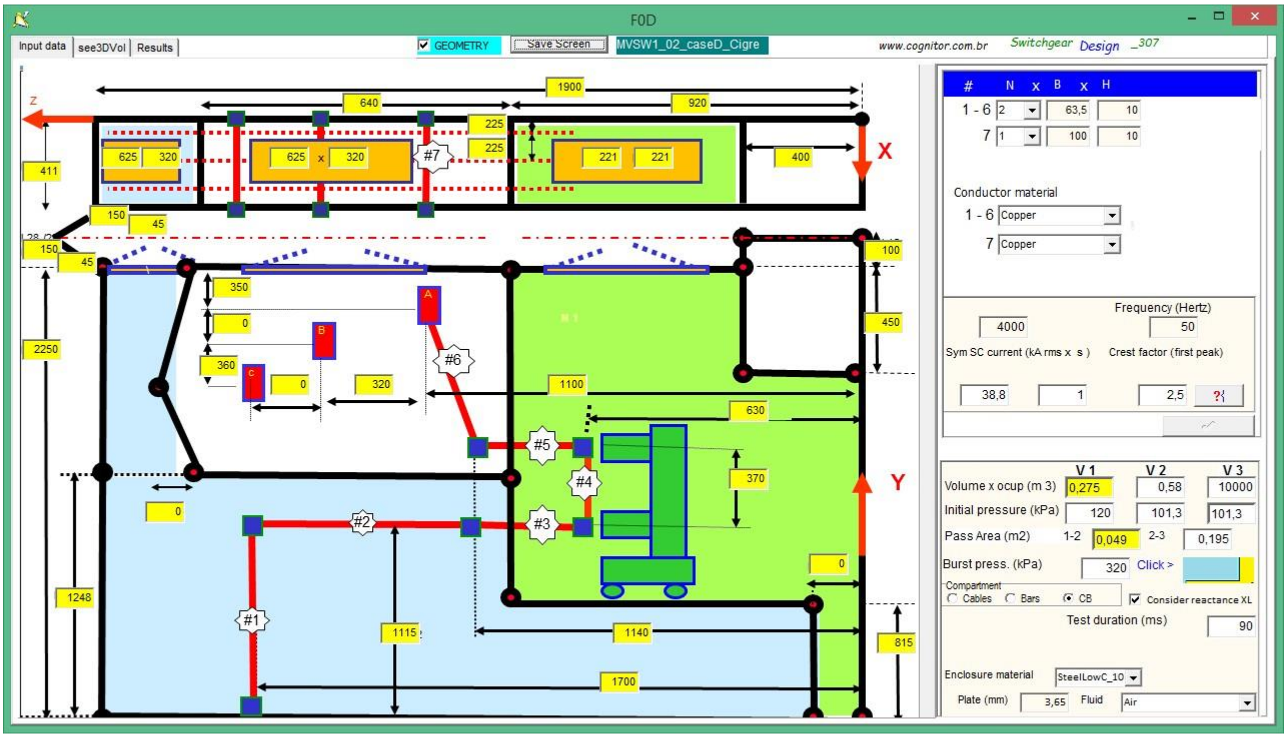


Table 10	MVSW1	INTERNAL ARC
Test in laboratory	Test Report 08-050	(Annex D)
Input data and results graph in Figure 7 Nomenclature of the data presented in Section 7 of the book		

Performance indicators	Obtained in test	Obtained in simulation	Difference
Maximum pressure (kPa) and overpressure above arc volume initial pressure ΔP (%)	154 kPa (52-56 %)	152 kPa (50%)	< 5%
Overpressure duration (ms)	46	42	< 15%
Integral of the overpressure x time duration curve (bar*s*1000)	-	9	
Duration to reach peak pressure (ms)	~ 15	11	(*)
Duration to return to 50% of the peak pressure (ms)	~ 25 (*)	20	
Arc voltage (V)	-	1251	
Arc velocity (m/s)	-	41	

(*) Laboratory oscillogram is small to allow a good evaluation of the values of the durations of time

Figure 8 MVSW1 Internal arc test
CASE D BROCHURE CIGRE (Annex E)
8 a – Input data MVSW1_02_caseD_Cigre



8 b – Results MVSW1_02_caseD_Cigre

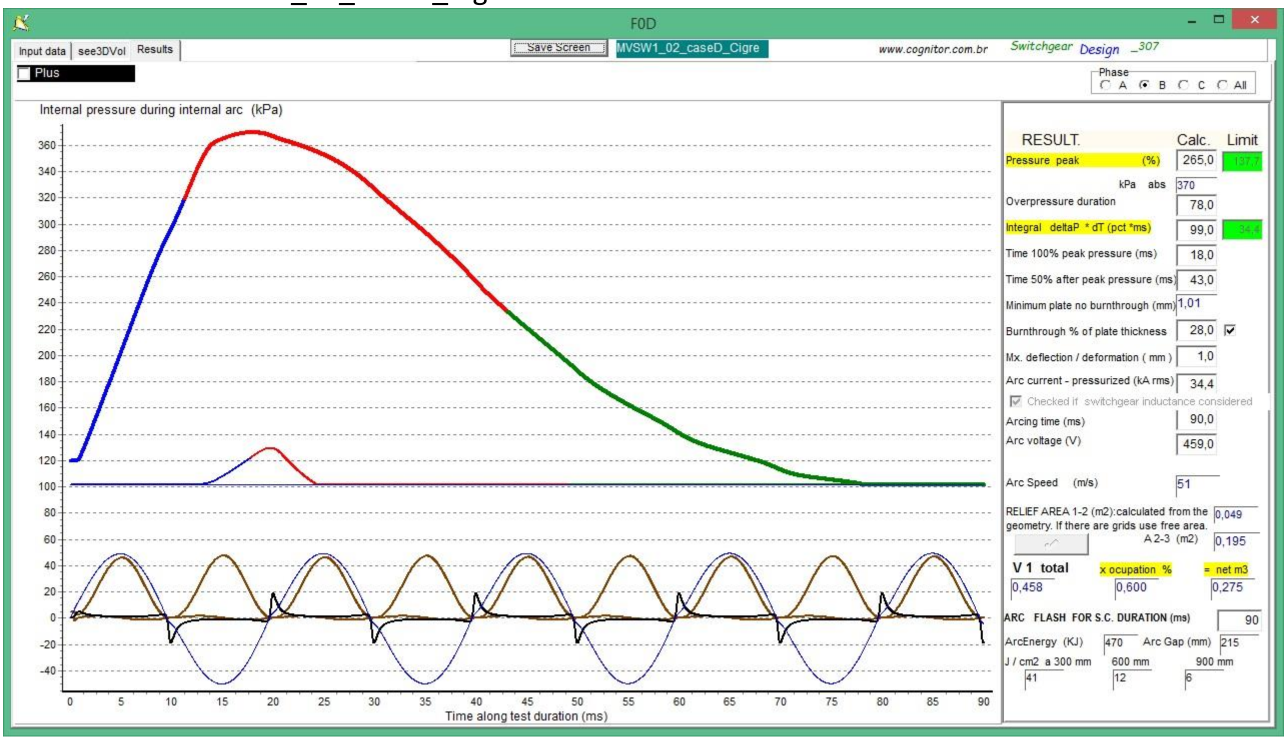
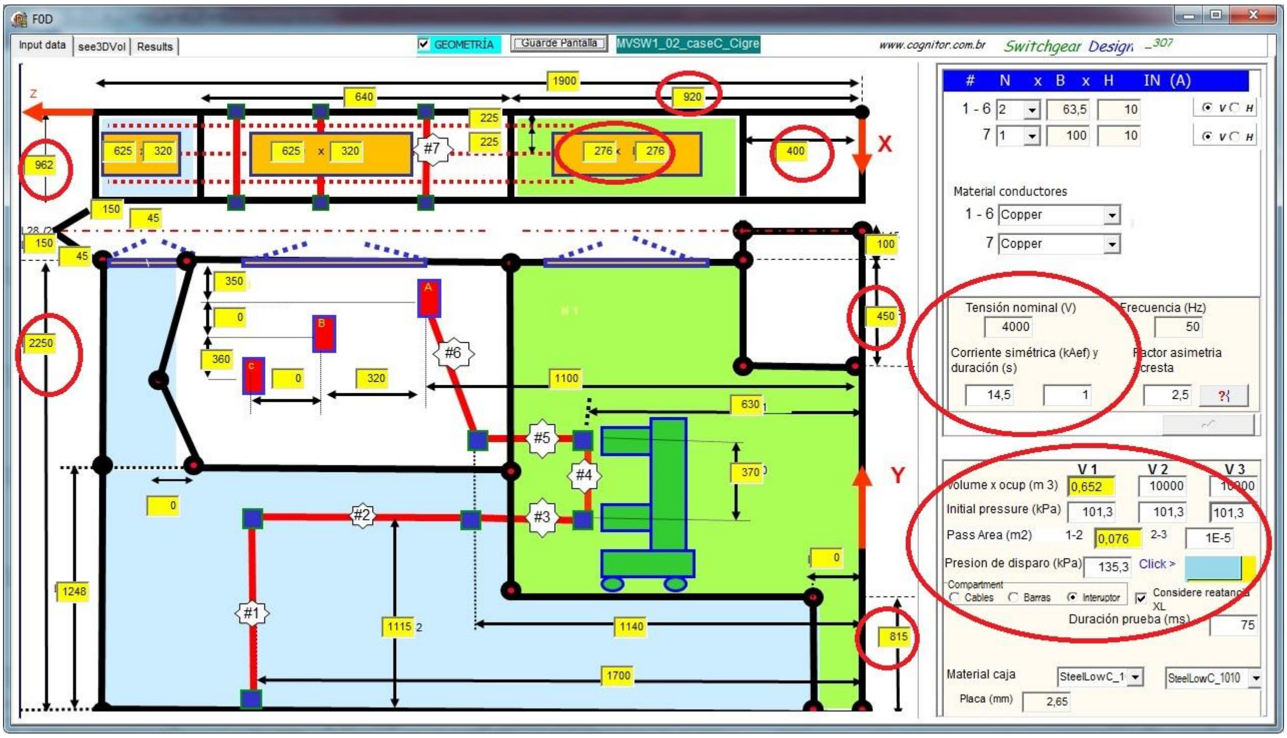


Table 11	MVSW1	INTERNAL ARC
CASE D	BROCHURE CIGRE	(Annex E)
Input data and results graph in Figure 8 Nomenclature of the data presented in Section 7 of the book		

Performance indicators	Obtained in test	Obtained in simulation	Differenc e
Maximum pressure (kPa) and overpressure above arc volume initial pressure ΔP (%)	353 kPa (volume V1) 138 kPa (V2)	370kPa (V1) 129 kPa (V2)	<15 % (V1) < 10 % (V2)
Overpressure duration (ms)	~ 72	78	< 5 %
Integral of the overpressure x time duration curve (bar*s*1000)	---	99	-
Duration to reach peak pressure (ms)	~ 13	18	
Duration to return to 50% of the peak pressure (ms)	~ 25	43	
Arc voltage (V)	Avg F-T 350 / 250	460	
Arc velocity (m/s)	-	51	

Figure 9	MVSW1	Internal arc test
CASE C	BROCHURE CIGRE	(Annex E)
9 a – Input data		MVSW1_02_caseC_Cigre



9 b – Results MVSW1_02_caseC_Cigre

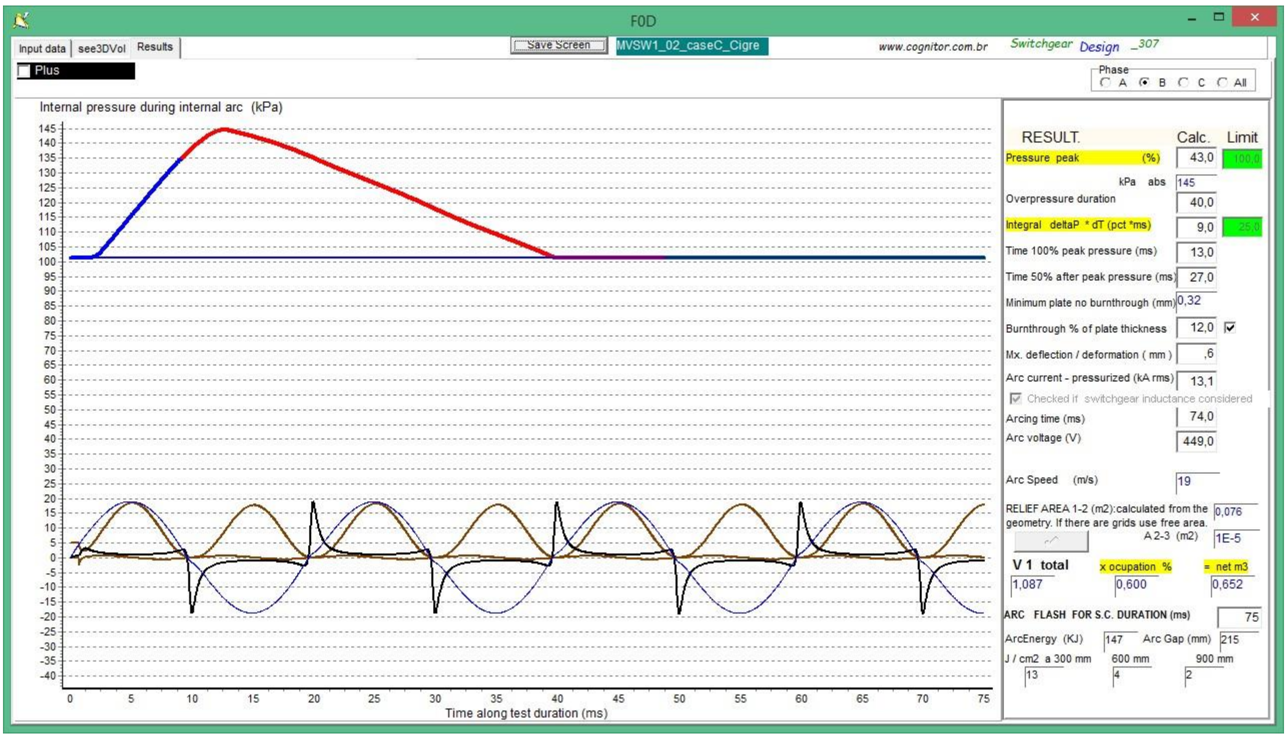
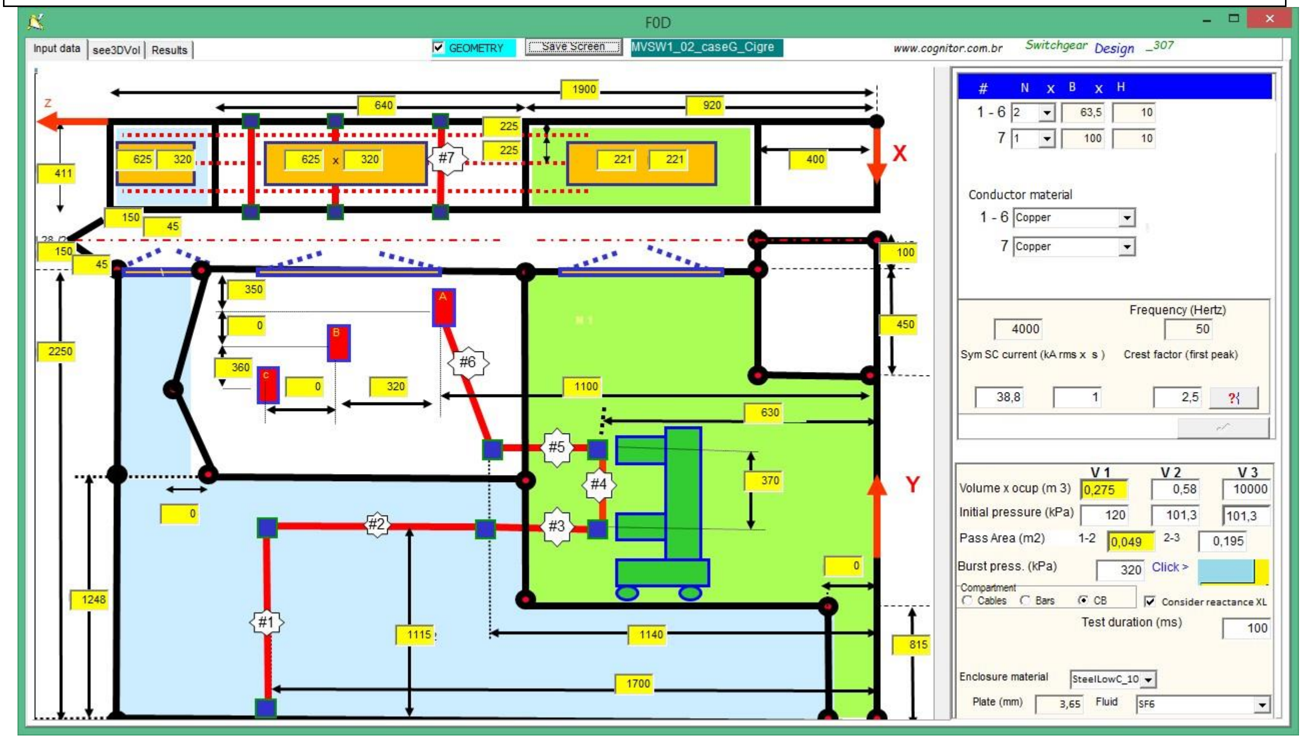


Table 12	MVSW1	INTERNAL ARC
CASE C	BROCHURE CIGRE	(Annex E)
Input data and results graph in Figure 9 Nomenclature of the data presented in Section 7 of the book		

Performance indicators	Obtained in test	Obtained in simulation	Difference
Maximum pressure (kPa) and overpressure above arc volume initial pressure ΔP (%)	138 kPa 2 arcs (*)	145 kPa 3 arcs (*)	< 10%
Overpressure duration (ms)	70	40	
Integral of the overpressure x time duration curve (bar*s*1000)		9	
Duration to reach peak pressure (ms)	20	13	
Duration to return to 50% of the peak pressure (ms)		27	
Arc voltage (V)	400	449	
Arc velocity (m/s)		19	

(*) Note: The calculations shown in Figure 9b were made using a number of arcs equal to 3, which is what is done in the software. In Table Cigrè Brochure in Annex E the number of "arcs was 2. With 3 arcs the calculated pressure is a little larger than with 2 arcs

Figure 10	MVSW1	Internal arc test
CASE G	BROCHURE CIGRE	(Annex E)
10 a – Input data	MVSW1_02_caseG_Cigre SF6	



10 b – Results MVSW1_02_caseG_Cigre

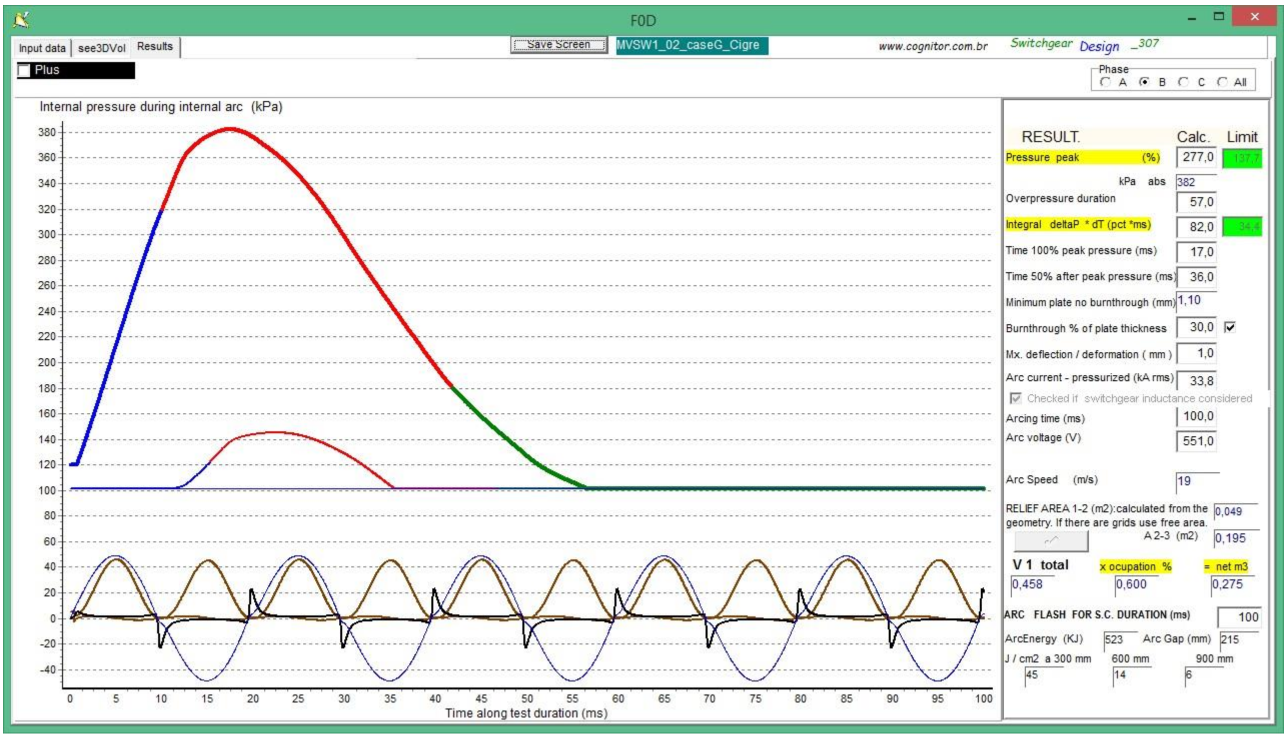


Table 13 MVSW1 INTERNAL ARC
CASE G BROCHURE CIGRE (Annex E) equal to CASE D (Table 11) but with SF6 instead of air
Input data and results graph in Figure 10 Nomenclature of the data presented in Section 7 of the book

Performance indicators	Obtained in test	Obtained in simulation	Difference
Maximum pressure (kPa) and overpressure above arc volume initial pressure ΔP (%)	330 kPa (V1) 170 kPa (V2)	381 kPa (V1) 145 kPa (V2)	<15 % (V1) <15 % (V2)
Overpressure duration (ms)	~90	57	
Integral of the overpressure x time duration curve (bar*s*1000)	---	82	-
Duration to reach peak pressure (ms)	~ 15	17	
Duration to return to 50% of the peak pressure (ms)	~ 40	36	
Arc voltage (V)	Medio F-T 400	551	
Arc velocity (m/s)	-	51	

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Figure 11 – MVSW1 – Internal arc test
Paper: Effect of Arc Energy Absorber in a Wind Turbine Switch unit IEE Transactions Vol. 28 N0 2 April 2013
11 a – Input data MVSW1_Absorber

UNDER PREPARATION

11 b – Results MVSW1_Absorber

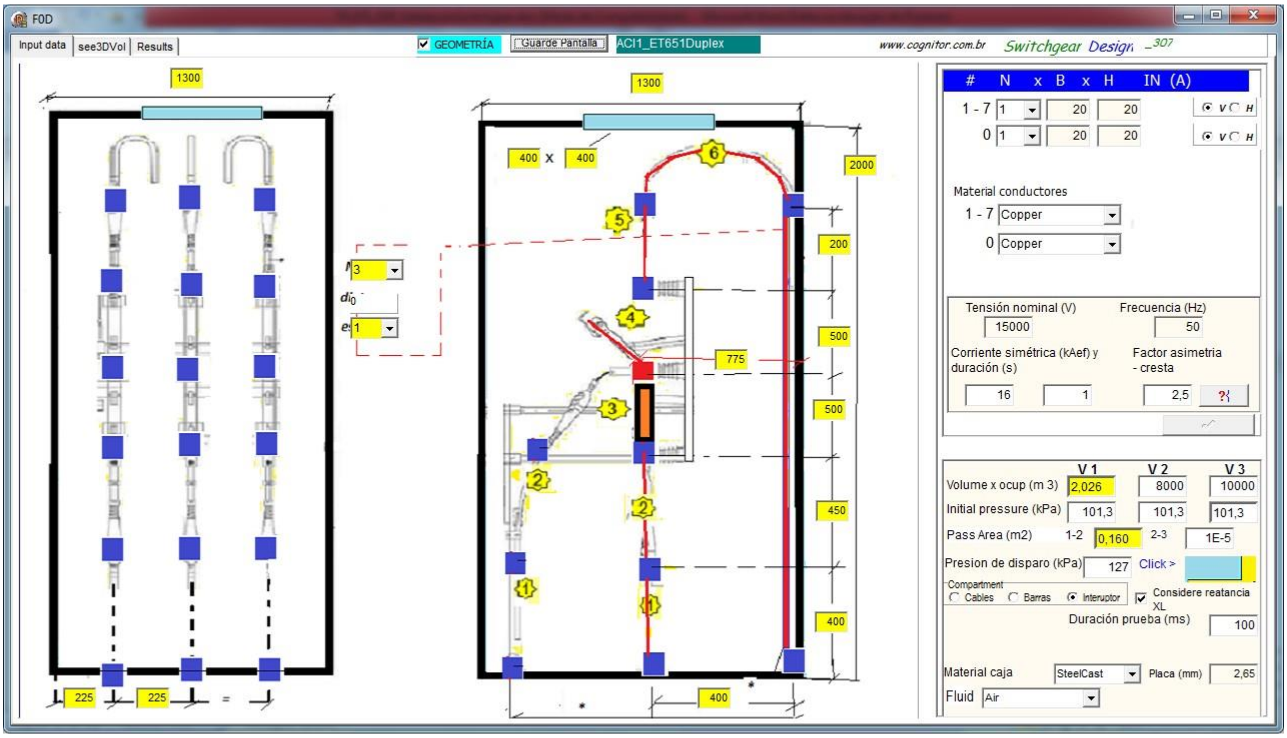
UNDER PREPARATION

Table 14 MVSW1 INTERNAL ARC
Paper: Effect of Arc Energy Absorber in a Wind Turbine Switch unit IEE Transactions Vol. 28 N0 2 April 2013
Input data and results graph in Figure 11 Nomenclature of the data presented in Section 7 of the book

Performance indicators	Obtained in test	Obtained in simulation	Difference
Maximum pressure (kPa) and overpressure above arc volume initial pressure ΔP (%)			
Overpressure duration (ms)			
Integral of the overpressure x time duration curve (bar*s*1000)			
Duration to reach peak pressure (ms)			
Duration to return to 50% of the peak pressure (ms)			
Arc voltage (V)			
Arc velocity (m/s)			

UNDER PREPARATION

Figure 12	ACI_1	INTERNAL ARC TEST
CASE CELDA ET651		(Annex G)
12 a – Input data		ACI1_ET651Duplex



12 b – Results ACI1_ET651Duplex

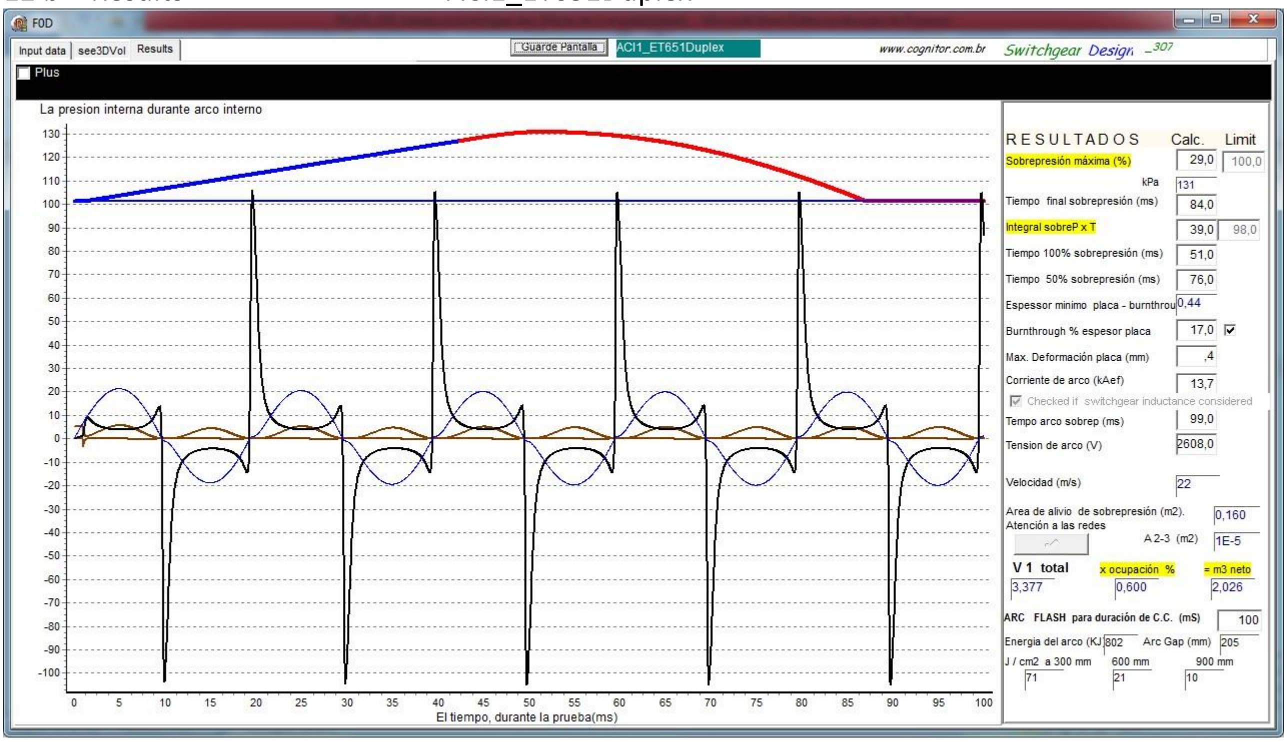


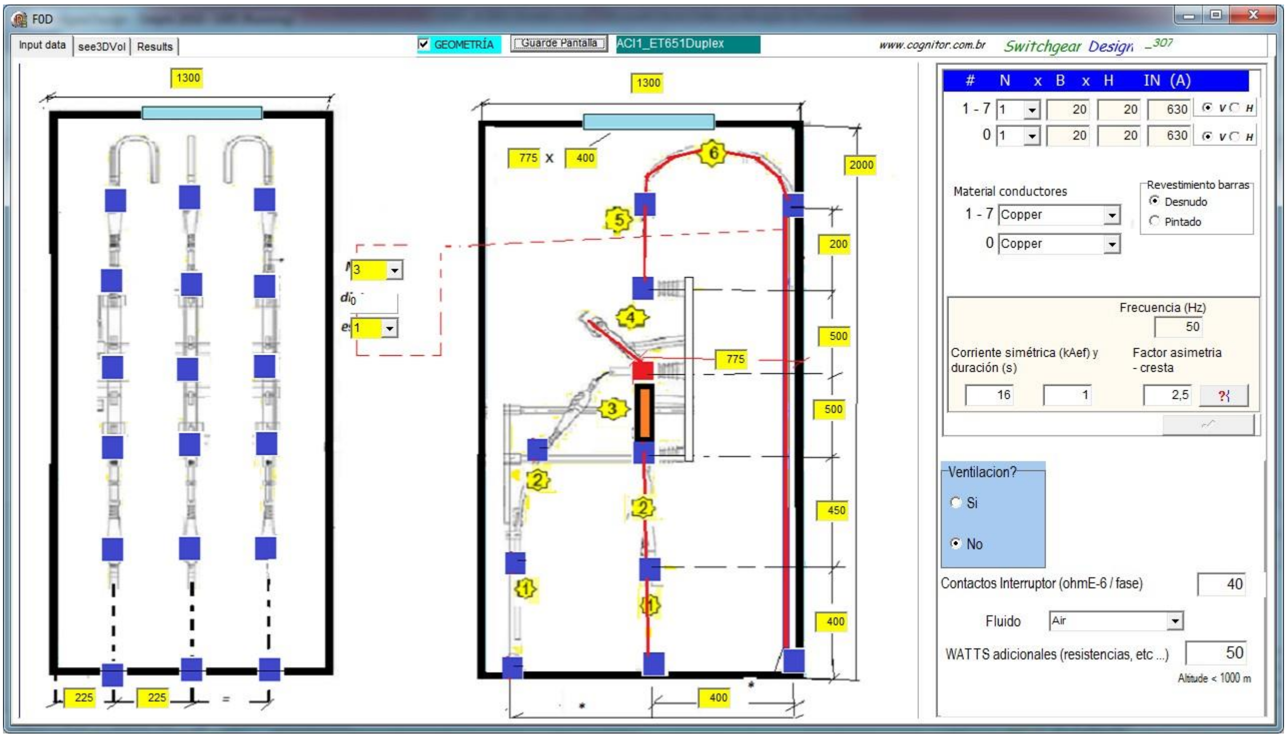
Table 15 – ACI1 – INTERNAL ARC		
CELDA ET 651	ACI1_ET651Duplex	(Annex G)
Input data and results graph in Figure 12 Nomenclature of the data presented in Section 7 of the book		

Performance indicators	Obtained in test	Obtained in simulation	Difference
Maximum pressure (kPa) and overpressure above arc volume initial pressure ΔP (%)		129	
Overpressure duration (ms)		93	
Integral of the overpressure x time duration curve (bar*s*1000)		43	
Duration to reach peak pressure (ms)		67	
Duration to return to 50% of the peak pressure (ms)		87	
Arc voltage (V)		2599	
Arc velocity (m/s)		22	

Waiting for some complete test report to enable validation

This is a typical medium voltage switchgear used in one South America country

Figure 13	ACI1	TEMPERATURE RISE TEST
	CASE CELDA ET651	(Annex G)
13 a – Input data		ACI1_ET651Duplex



13 b – Result ACI1_ET651Duplex

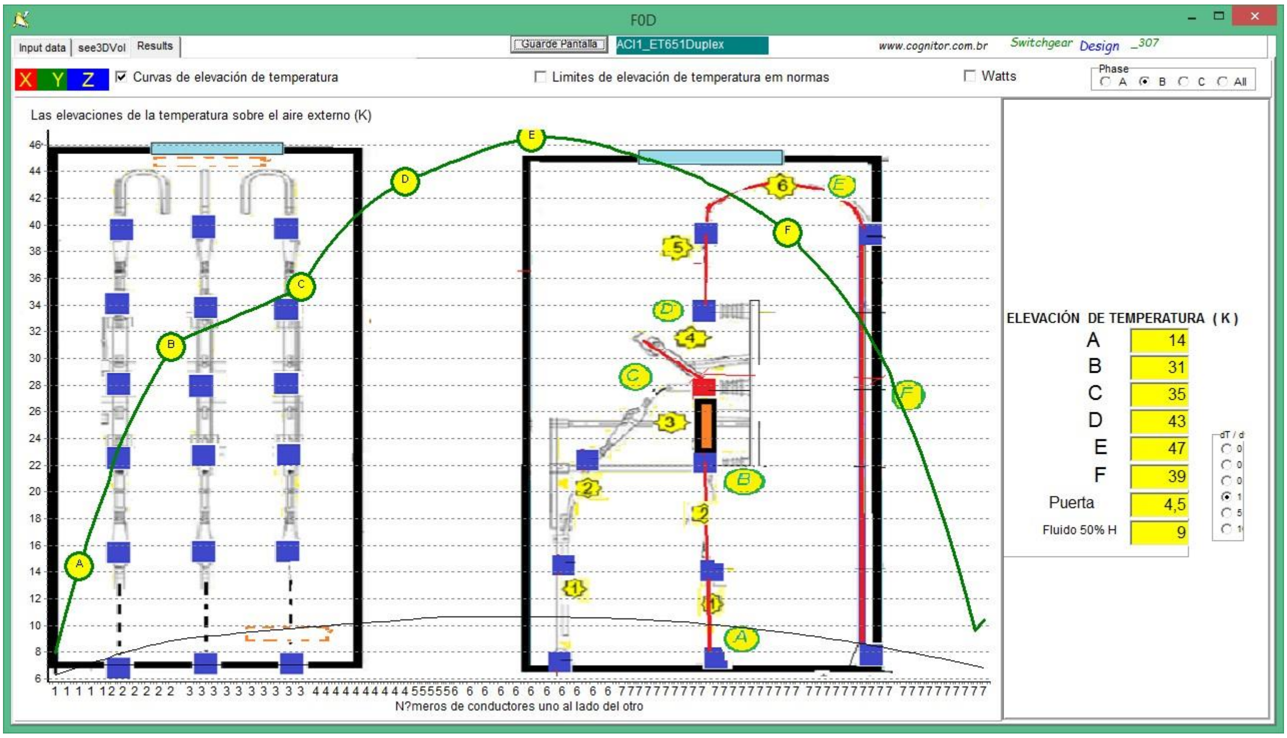


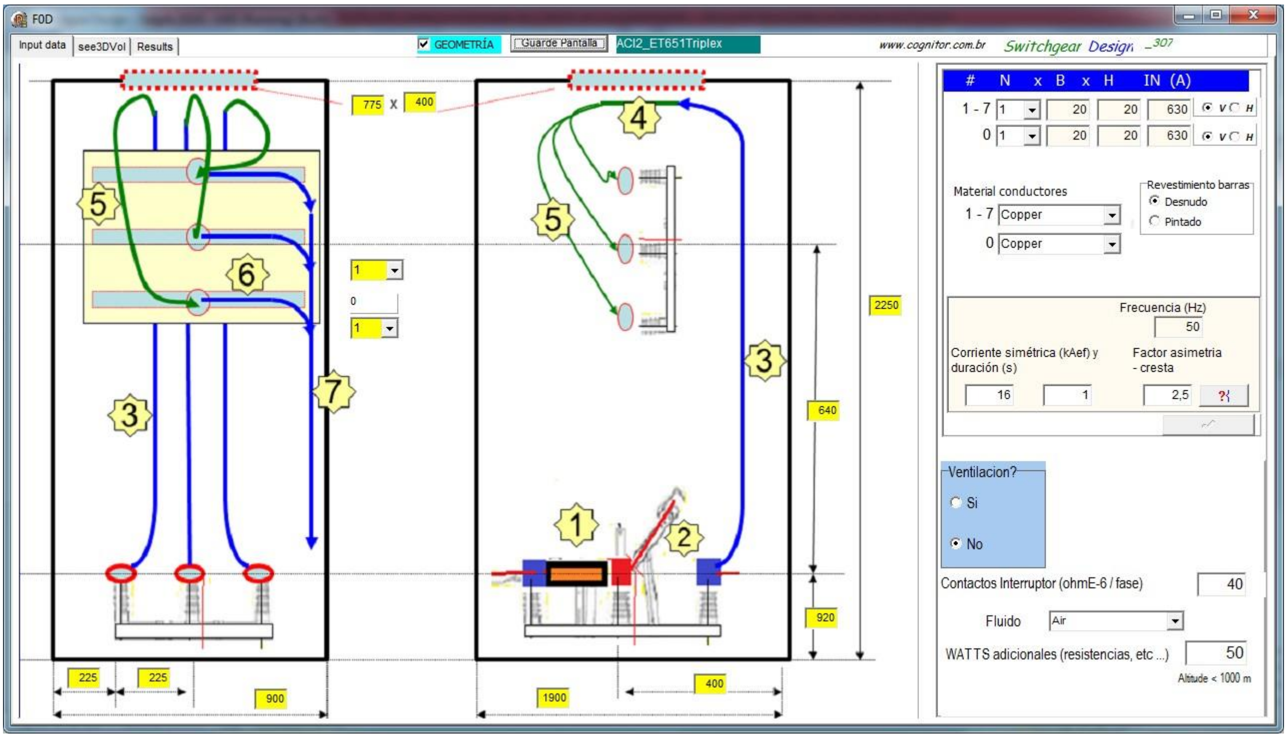
Table 16 – ACI_1 – Temperature rise test
CASO CELDA ET 651 ACI1_ET651Duplex (Annex G)
Input data and results graph in Figure 13 Nomenclature of the data presented in Section 7 of the book Bare bus bar Without ventilation openings Connection / joint resistance – 40 μΩ

Measuring point	Test temperature rise (K)	Simulation (K)	Difference
A - Terminals for connection to external conductors		14	
B – Cable near the fuse		31	
C – Terminal of the switch		35	
D – Terminal of the switch		43	
E – Cable in the top part		46	
F – Short circuit point		39	
Door		4,5	
Internal air (50% H)		9	

Waiting for some complete test report to enable validation

This is a typical medium voltage switchgear used in one South America country

Figure 14	ACI_2	Temperature rise test
CASE CELDA ET651		(Annex G)
14 a – Input data		ACI`2_ET651Triplex



14 b – Resultados ACI_2_ET651TRIPLEX

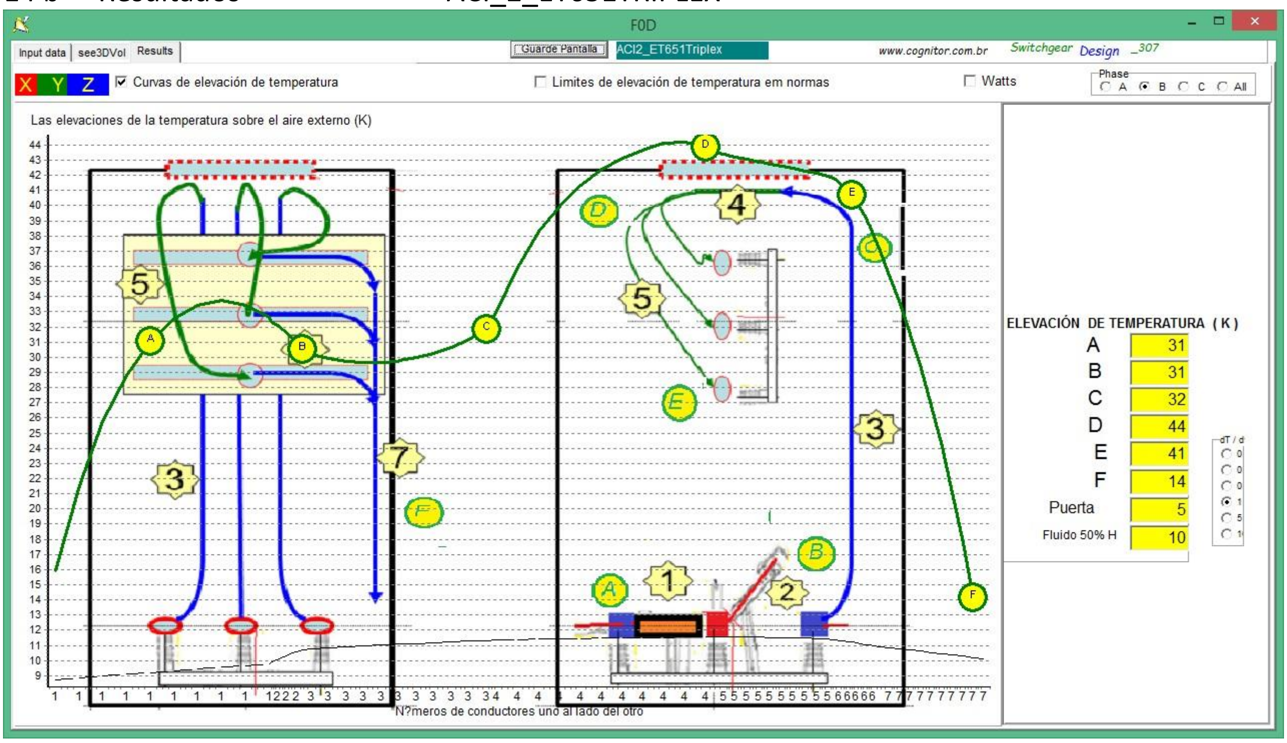


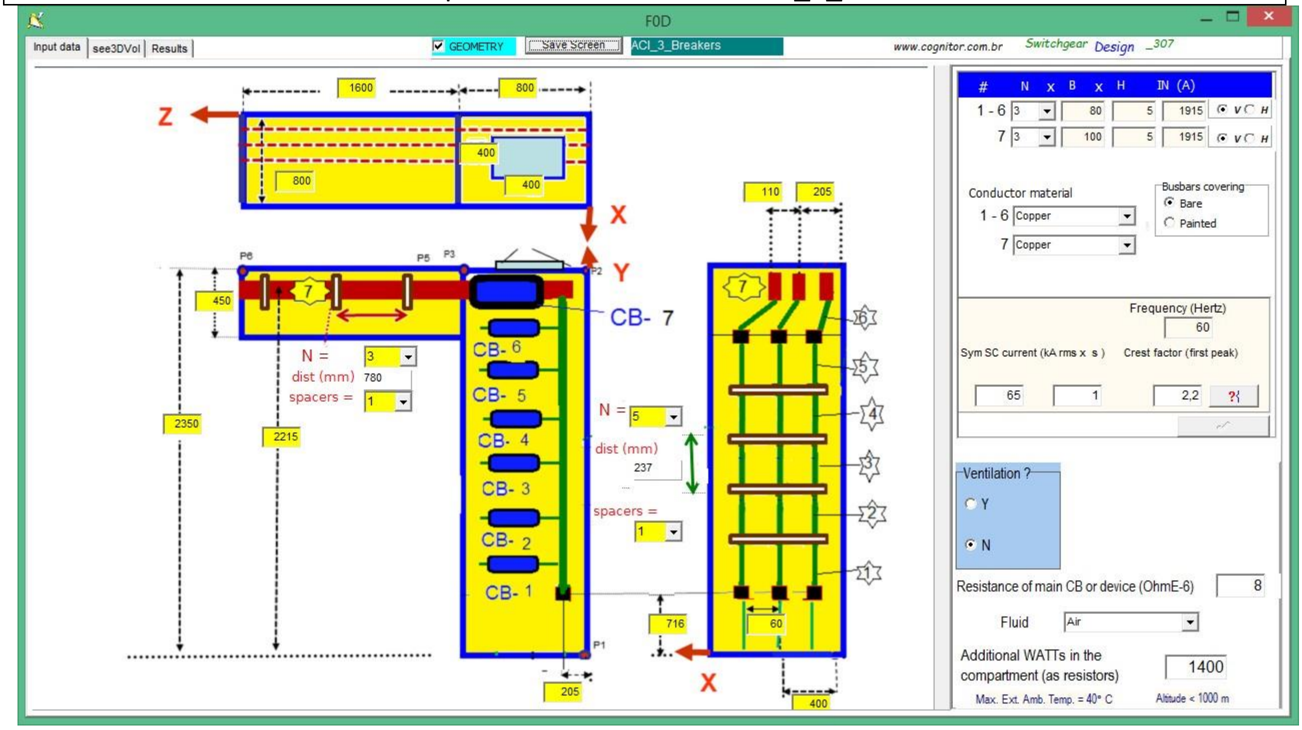
Table 17	ACI_2	– Temperature rise test
CASO CELDA ET 651	ACI_2_ET651TRIPLEX	(Annex G)
Input data and results graph in Figure 14 Nomenclature of the data presented in Section 7 of the book		
Bare bus bar	Without ventilation openings	
Connection / joint resistance – XXX μΩ		

Measuring point	Test temperature rise (K)	Simulation (K)	Difference
A - Terminals for connection to external conductors		31	
B – Cable near the switch		31	
C – Cable upper part		32	
D – Terminal of the switch		43	
E – Terminals		41	
F – Cable lower part		14	
Door		4	
Internal air (50% H)		10	

Waiting for some complete test report to enable validation

This is a typical medium voltage switchgear used in one South America country

Figure 15	ACI_3	TEMPERATURE RISE TEST
CASE ACI_3_Breakers 1		(Annex G)
15a – Input data		ACI_3_Breakers



15 b – Resultados ACI_3_Breakers

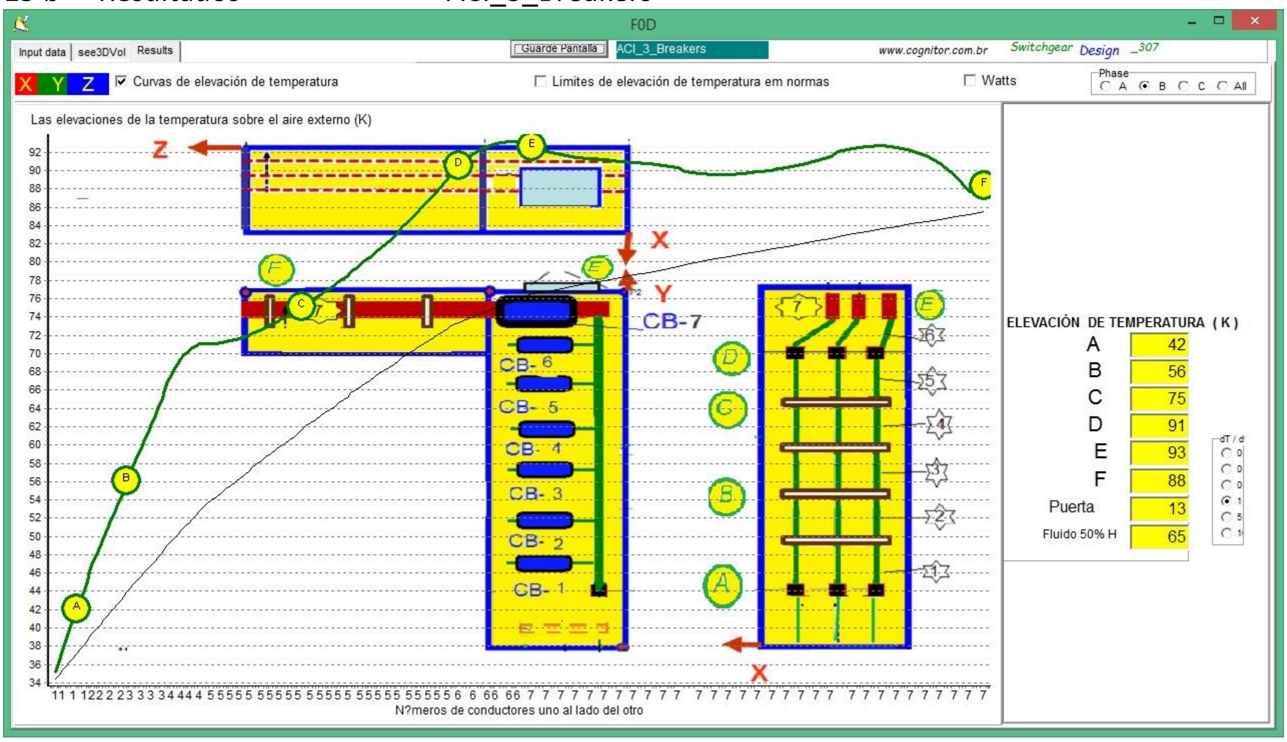


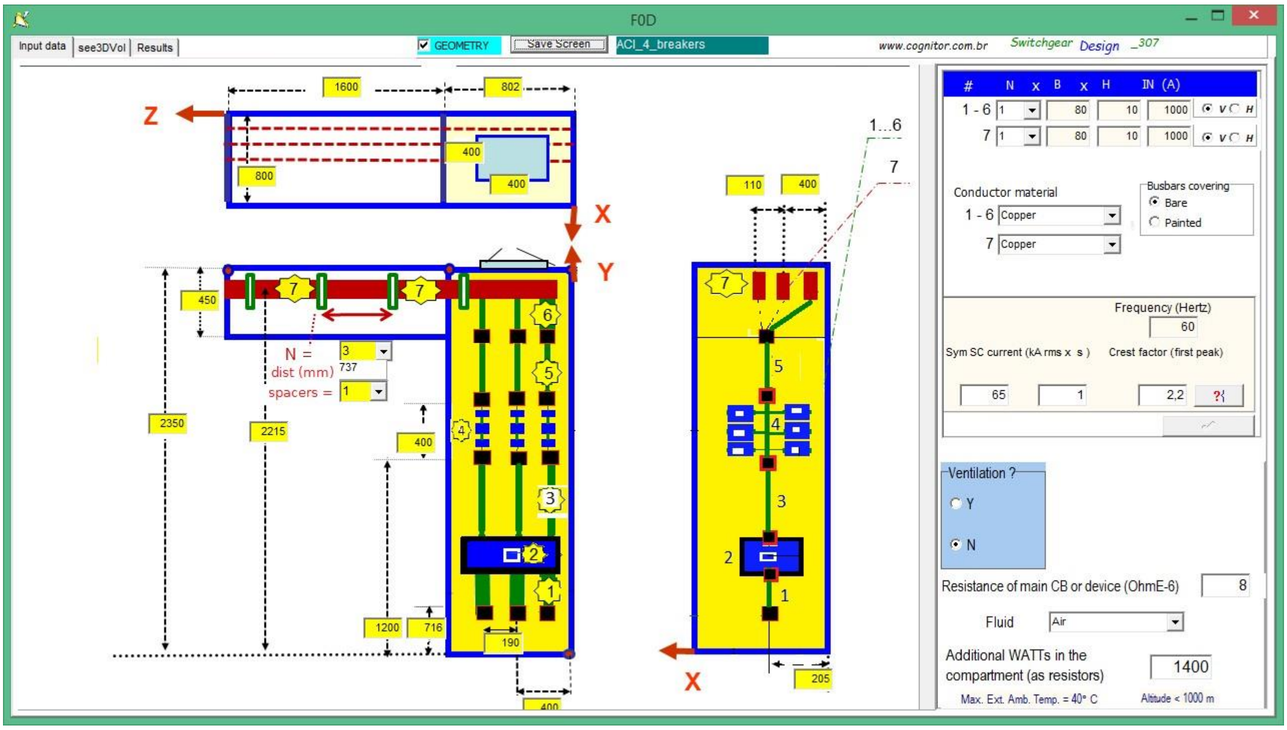
Table 18	ACI_3	TEMPERATURE RISE TEST
	ACI_3_Breakers	(Annex G)

Input data and results graph in Figure 15
Nomenclature of the data presented in Section 7 of the book

Bare bus bar Without ventilation openings
Each joint resistance – 8 μΩ + 1400 W (sum of circuit breakers)

Measuring point	Test temperature rise (K)	Simulation (K)	Difference
A		42	
B		56	
C		75	
D		91	
E		93	
F		88	
Door		14	
Internal air (50% H)		65	

Figure 16	ACI_4	TEMPERATURE RISE TEST
CASE ACI_4_Breakers		(Annex G)
16a – Input data		ACI_4_Breakers



16 b – Results ACI_4_Breakers

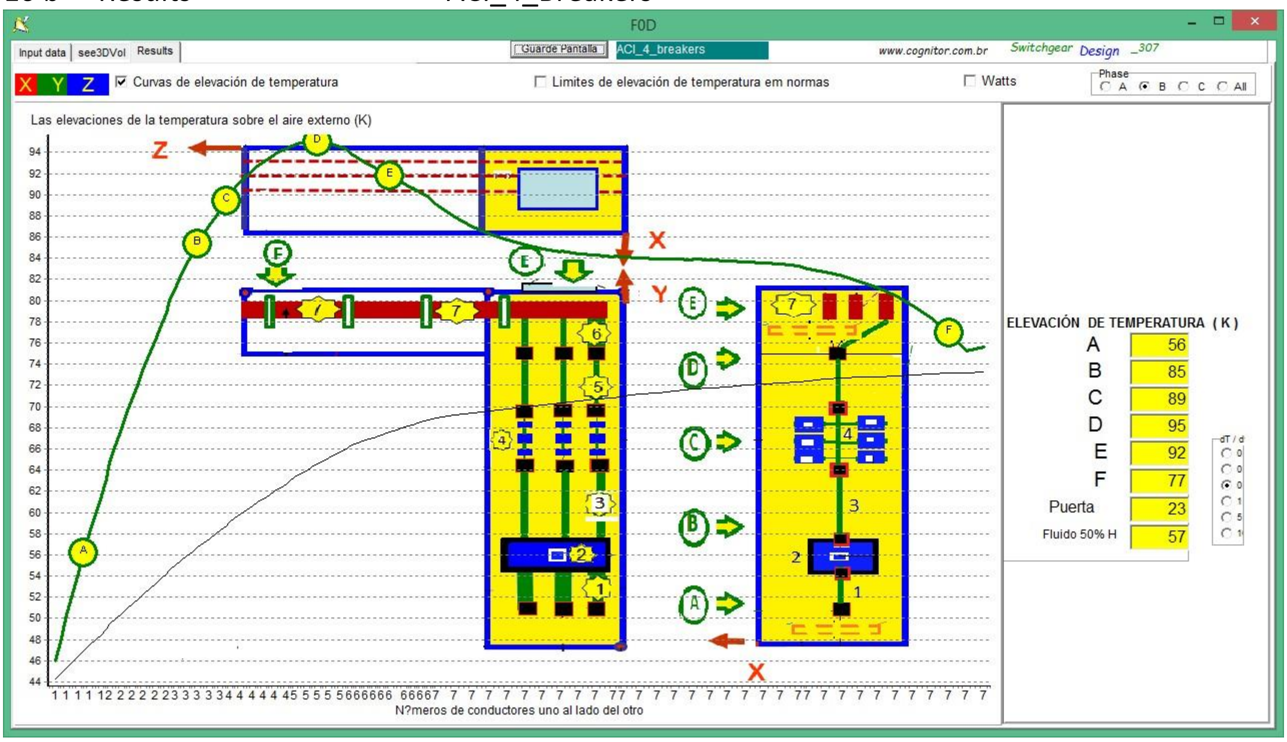


Table 19	ACI_4 – TEMPERATURE RISE TEST
ACI_4_Breakers	(Annex G)
Input data and results graph in Figure 16 Nomenclature of the data presented in Section 7 of the book Bare bus bar Without ventilation openings Connection / joint resistance – 8µΩ + 1400 W	

Measuring point	Test temperature rise (K)	Simulation (K)	Difference
A		56	
B		85	
C		89	
D		95	
E		82	
F		77	
Door		23	
Internal air (50% H)		57	

6. CRITERIA FOR ACCEPTANCE OF SIMULATION RESULTS (SOFTWARE FIT OR NOT THE INTENDED USE?).

Unfortunately there is no IEC or IEEE technical standard that define criteria and therefore we are using as a criterion the values shown in the draft standard proposed by Sergio Feitoza (Table 1 in this report)
Based on these values it can be said that these simulations give quite acceptable results whenever the correct input data is used.

7. REQUIREMENTS OF THE OPERATING SYSTEM

There are no special requirements for computers. Throughout the several courses already applied, the software worked properly.

8. PROGRAMMING LANGUAGE

The software was developed originally in Delphi 7 (formerly Borland and now Embarcadero) and the most recent version is compiled in Delphi 2010

9. INSTRUCTIONS FOR INSTALATION AND USE.

The conditions of use are "usage is at your own risk" The author of the software and Cognitor are not responsible for any result or use given to the results.

After downloading or copying the file SetUp_SwitchgearDesignEN.zip installation (size of 4.2 MB) save it to some directory on your computer.

To install SwitchgearDesign_307 unzip the file and then click the right mouse button on the uncompressed file and then click with the left button on "Run as Administrator".

Give OK on everything and when prompted for the password during the installation type para150413kalo

After installation, a SwitchgearDesign icon will be created on the "desktop" and in the list of programs start button.

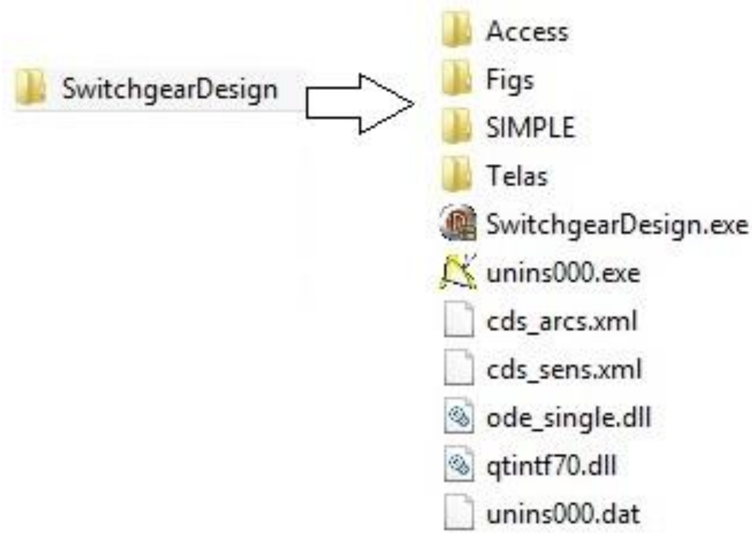
On your computer a single directory c:\SwitchgearDesign will be created where the all the necessary files will be installed.

If it is not automatically created, you may create a desktop shortcut to the file

C: \ SwitchgearDesign \SwitchgearDesign.exe

The SwitchgearDesign.exe file, the tables of the database and all other files will be installed in this directory and its subdirectories. Nothing more will be installed outside this directory.

Here is what you will see:



This is installer was designed intending to enable software to work fine work fine on all computers and operating systems.

Although we already have it installed on, many different computers sometimes when installed on, another PC may be necessary to add files. A typical error message is ... “This file is missing.”

Therefore, if an error occurs in the installation note the error message and send me to the email sergiofeitoza@cognitor.com.br .

This software, as provided in the training program is for use only within the participant’s company who received the installer.

Passing on copies to others without written authorization from Cognitor is not permitted.

10.Annex A – METHODOLOGY, VALIDATION AND REFERENCES

The method of calculation and information on the validation of the simulations are presented in the following and other articles available at http://www.cognitor.com.br/en_download.htm :

[1] Book "Reference text for the courses SWITCHGEAR, BUSWAYS & ISOLATORS and SUBSTATIONS AND LINES EQUIPMENT"
Author: Sergio Feitoza Costa , 2013
Free download in the site http://www.cognitor.com.br/Book_SE_SW_2013_ENG.pdf

[2] A "GUIDE" FOR THE USE OF CALCULATIONS AND SIMULATION OF LABORATORY TESTS FOR INCREASING THE COMPETITIVENESS OF THE ELECTRIC INDUSTRY
Download : http://www.cognitor.com.br/Article_Competitivity_Eng_04102011.pdf

[3] "VALIDATION OF SIMULATIONS OF ELECTRODYNAMICAL FORCES, TEMPERATURE-RISE AND INTERNAL ARC TESTS IN SWITCHGEAR (& main parts of a code) (2010)
Author: Sergio Feitoza Costa
Presented at the CIGRE Technical Seminar "Modeling and Testing of Transmission and Distribution Switchgear" March 24, 2010 Brisbane – Australia
Download: http://www.cognitor.com.br/Validation_Simulations_English.pdf

[4] VALIDAÇÃO DE SIMULAÇÕES DE ENSAIOS DE ARCO INTERNO, DE FORÇAS ELETRODINÂMICAS E DE ELEVAÇÃO DE TEMPERATURA (e partes do código-fonte) . (2010)
Autoria: Sergio Feitoza Costa
Revista ELETRICIDADE MODERNA – Junho 2010 - pag.194
Download http://www.cognitor.com.br/Validation_Simulations_Portugues.pdf

[5] "CELDAS, CUADROS, CANALIZACIONES Y OTROS EQUIPOS DE TRANSMISION Y DISTRIBUCION: FALTA ALGO EN LAS NORMAS IEC Y EN LAS ESPECIFICACIONES DE USUARIOS"
Autoría: Sergio Feitoza Costa
http://www.cognitor.com.br/Switchgear_Busbar_Standards_Review_Spanish.pdf
Publicado en Revista RBE Energía (Madrid / España) - Enero/Febrero 2010 - pag 62 -
http://www.cognitor.com.br/RBE_Energia.zip

[6] "Simulation, IEC STANDARDS AND TESTING LABORATORIES: JOINING THE PIECES FOR HIGHER QUALITY HV EQUIPMENT".
Author: Sergio Feitoza Costa
Paper published PS1-06 in the CIGRÈ International Technical Colloquium - Rio de Janeiro - September 2007 http://www.cognitor.com.br/Artigo_Cigre_SergioFeitozaCosta_Cognitor.pdf

Published also in in Energy Pulse weekly, September, 28 , 2010
http://www.energypulse.net/centers/article/article_display.cfm?a_id=2338

[7] VALIDACIÓN DE LOS INFORMES DE ENSAYO EMITIDOS POR LABORATORIOS DE PRUEBAS RECONOCIDOS
Revista SETOR ELETRICO - Edição 82 - Novembro 2012
http://www.cognitor.com.br/ValidatingReports_Esp.pdf

[8] PAINÉIS , QUADROS E BARRAMENTOS: FALTA ALGO NAS NORMAS IEC E NAS ESPECIFICAÇÕES DE USUARIOS
Autoria: Sergio Feitoza Costa
Publicado na edição de junho 2010 da Revista O SETOR ELÉTRICO - pag.146
Download http://www.cognitor.com.br/Switchgear_Busbar_Standards_Review_Portugues.pdf

[9] "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
CIGRE WG A3-20 publication A3-210 (2008) - Presented at the Congress Cigre - Paris 2008

[10] SIGNIFICANT PARAMETERS IN INTERNAL ARC SIMULATION AND TESTING,
CIGRE WG A3.24, CIGRE A3 SESSION, 2009
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,

[11] Paper FINDING THE OPTIMAL SWITCHGEAR DESIGN: A comparison between aluminum and copper and an idea of new concept.
Autoría: Sergio Feitoza Costa & Marlon Campos

Publicado en Portugués en la edición Enero 2014 de la Revista O SETOR ELÉTRICO bajo el título de ALUMINIO X COBRE EN PROYECTOS DE LOS PANELES ELÉCTRICOS (PÁGINA 136)
Download : http://www.cognitor.com.br/DesignOptimization.pdf

11. Annex B - TECHNICAL STANDARDS OF REFERENCE

[12] IEC 62271-200 Ed. 2.0 b:2011 : High-voltage switchgear and controlgear - Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV

[13] IEC TR 60890: A Method of Temperature-rise Assessment by Extrapolation for Partially Type-Tested Assemblies (PTTA) of Low-Voltage Switchgear and Controlgear

[14] IEC 61117: Method for assessing the short-circuit withstand strength of partially type-tested assemblies (PTTA)

[15] IEC 60865-1: Short-circuit currents – calculation of effects – Part 1: Definitions and calculation

[16] IEC 60865-2: Short-circuit currents – calculation of effects – Part 2: Examples of calculation

[17] IEC TR 60943: Guidance concerning the permissible temperature rise for parts of electrical equipment, in particular for terminals

[18] CIGRE Brochure No. xxx, 2014, “Tools for the simulation of effects of the internal arc in MV and HV switchgear”

[19] IEC 61439-1 Ed. 2.0 (2011) – Low-voltage switchgear and controlgear assemblies - Part 1: General rules

[20] IEC 61439-2 Ed. 2.0 (2011) – Low-voltage switchgear and controlgear assemblies - Part 2: Power switchgear and controlgear assemblies

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

[22] ABB Switchgear Manual - ABB Pocket Book - Switchgear Manual - 10th revised edition Edited by ABB Calor Emag Schaltanlagen AG Mannheim and ABB Calor Emag Mittelspannung GmbH Ratingen - Previous editions: (published till 1987 by BBC Brown Boveri, since 1988 by ABB) - First edition 1948 - http://pt.scribd.com/doc/23692182/ABB-Switchgear-Manual-11th-Ed-2006

[23] Sergio Feitoza Costa´s M.Sc. thesis on Electrodynamical Forces at http://www.cognitor.com.br/electrodynamic.pdf COPPE / UFRJ – Janeiro - 1981

12. Annex C – CALCULATIONS IN IEC 865-2 – 1994

The standard can be purchased in the site of IEC WEBSTORE http://webstore.iec.ch/

RAPPORT TECHNIQUE

TECHNICAL REPORT

CEI
IEC
865-2

Première édition
First edition
1994-06

Courants de court-circuit – Calcul des effets –

Partie 2:
Exemples de calcul

Short-circuit currents – Calculation of effects –

Part 2:
Examples of calculation

865-2 © IEC:1994 – 9 –

SHORT-CIRCUIT CURRENTS – CALCULATION OF EFFECTS

Part 2: Examples of calculation

1 Scope and object

The object of this IEC Technical Report is to show the application of procedures for the calculation of mechanical and thermal effects due to short circuits as presented in IEC 865-1. Thus, this technical report is an addition to IEC 865-1. It does not, however, change the basis for standardized procedures given in that publication.

NOTES

1 The examples in this Technical Report illustrate how to make the calculations according to IEC 865-1 in a simplified and easy-to-follow manner. They are not intended as a check for computer programs.

2 The numbers in parentheses at the end of the equations refer to the equations in IEC 865-1.

3 The system voltages are referred to as nominal voltages.

2 Reference document

IEC 865-1: 1993, *Short-circuit currents – Calculation of effects – Part 1: Definitions and*

CONTENTS

Phone : 55-21-2465 3689 or 55-21-33934600 or cell 55-21-98887 4600
E-mail: sergiofeitoza@cognitor.com.br Site: www.cognitor.com.br

4 Example 1 – Mechanical effects on a 10 kV arrangement with single rigid conductors

The basis for the calculation in this example is a three-phase 10 kV busbar with one conductor per phase. The conductors are continuous beams with equidistant simple supports. The conductor arrangement is shown in figure 1.

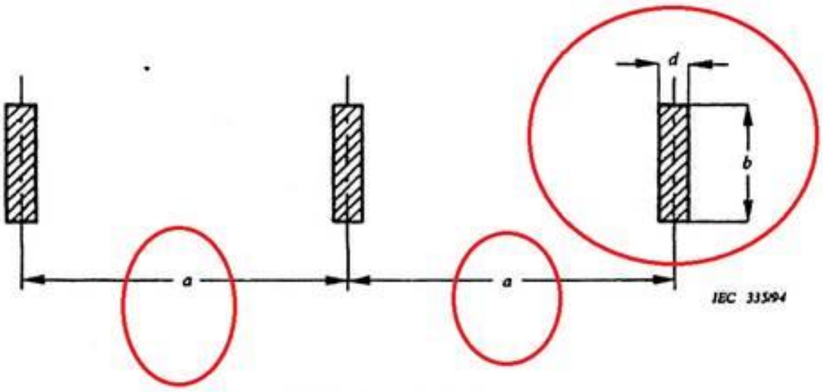


Figure 1 – Conductor arrangement

4.1 *Data*

Software input

$1{,}35\sqrt{2} = 1{,}90$

Three-phase initial symmetrical short-circuit current (r.m.s.)	I''_{k3} = 16 kA
Factor for calculation of peak short-circuit current	κ = 1,35
System frequency	f = 50 Hz
No automatic reclosing	
Number of spans	≥ 3
Distance between supports	l = 1 m
Centre-line distance between conductors	a = 0,2 m
Rectangular conductor of AlMgSi0,5	
– Dimensions	b = 60 mm d = 10 mm
– Mass per unit length	m' = 1,62 kg/m
– Young's modulus	E = 70 000 N/mm^2
– Stress corresponding to the yield point	$R_{p0,2}$ = 120 N/mm^2 up to 180 N/mm^2

4.2 *Maximum force on the central main conductor*

$$F_{m3} = \frac{\mu_0}{2\pi}\,\frac{\sqrt{3}}{2}\,i_{p3}^2\,\frac{l}{a_m} = \frac{4\pi \cdot 10^{-7}}{2\pi}\,\frac{\text{Vs}}{\text{Am}} \times \frac{\sqrt{3}}{2} \times (30{,}6 \cdot 10^3\ \text{A})^2 \times \frac{1{,}00\ \text{m}}{0{,}202\ \text{m}} = 803\ \text{N} \qquad (2)$$

where

$i_{p3} = \sqrt{2}\ \kappa\, I''_{k3} = \sqrt{2} \times 1{,}35 \times 16\ \text{kA} = 30{,}6\ \text{kA} = 30{,}6 \cdot 10^3\ \text{A}$

and the effective distance between the main conductors

$$a_m = \frac{a}{k_{12}} = \frac{0{,}20\ \text{m}}{0{,}99} = 0{,}202\ \text{m} \qquad (6)$$

with k_{12} according to IEC 865-1 figure 1 for $b/d = 6$, $a_{1s} = a$ and $a/d = 20$.

4.3 *Conductor stress and forces on supports*

Calculation can be made according to the following 4.3.1 or 4.3.2.

4.3.1 *Simplified method*

4.3.1.1 *Conductor bending stress*

$$\sigma_{tot} = \sigma_m = V_\sigma\, V_r\, \beta\, \frac{F_{m3}\, l}{8Z} \qquad (9{,}12)$$

$$= 1{,}0 \times 0{,}73 \times \frac{803\ \text{N} \times 1{,}00\ \text{m}}{8 \times 1 \cdot 10^{-6}\ \text{m}^3} = 73{,}3 \cdot 10^6\ \text{N/m}^2 = 73{,}3\ \text{N/mm}^2$$

where

$V_\sigma V_r = 1{,}0 = (V_\sigma V_r)_{max}$ according to IEC 865-1, table 2

$\beta = 0{,}73$ according to IEC 865-1, table 3

$$J = \frac{bd^3}{12} = \frac{0{,}06 \times 0{,}010^3}{12}\ \text{m}^4 = 0{,}5 \cdot 10^{-8}\ \text{m}^4$$

$$Z = \frac{J}{d/2} = \frac{0{,}5 \cdot 10^{-8}\ \text{m}^4}{0{,}005\ \text{m}} = 1 \cdot 10^{-6}\ \text{m}^3$$

The busbars are assumed to withstand the short-circuit force if

$$\sigma_{tot} \le q\, R_{p0.2} \qquad (13)$$

With the lower value of $R_{p0,2}$. For a rectangular cross-section $q = 1{,}5$, see IEC 865-1, table 4. This gives:

$$\sigma_{tot} = 73{,}3\ \text{N/mm}^2 \text{ less than } 1{,}5 \times 120\ \text{N/mm}^2 = 180\ \text{N/mm}^2$$

4.3.1.2 *Bending force on the supports*

$$F_d = V_F\, V_r\, \alpha\, F_{m3} \qquad (15)$$

According to IEC 865-1, table 2 with the upper value of $R_{p0,2}$ it is:

$$\frac{\sigma_{tot}}{0,8 \cdot R_{p0,2}} = \frac{73,3\ \text{N/mm}^2}{0,8 \times 180\ \text{N/mm}^2} = 0,509$$

therefore, with a three-phase short circuit

$$0,370 < \frac{\sigma_{tot}}{0,8 \cdot R_{p0,2}} < 1$$

Hence

$$V_F\, V_r = \frac{0,8 \cdot R_{p0,2}}{\sigma_{tot}} = \frac{0,8 \times 180\ \text{N/mm}^2}{73,3\ \text{N/mm}^2} = 1,97$$

For the outer supports (A) is with $\alpha_A = 0,4$, see IEC 865-1, table 3:

$$F_{dA} = V_F V_r \alpha_A F_{m3} = 1,97 \times 0,4 \times 803\ \text{N} = 633\ \text{N}$$

For the inner supports (B) is with $\alpha_B = 1,1$, see IEC 865-1, table 3:

$$F_{dB} = V_F V_r \alpha_B F_{m3} = 1,97 \times 1,1 \times 803\ \text{N} = 1\ 740\ \text{N}$$

4.3.2 *Detailed method*

4.3.2.1 *Natural frequency f_c and factors V_F, V_r and V_σ*

$$f_c = \frac{\gamma}{l^2}\sqrt{\frac{EJ}{m'}} = \frac{3,56}{(1,00\ \text{m})^2}\sqrt{\frac{7 \cdot 10^{10}\ \text{N/m}^2 \times 0,5 \cdot 10^{-8}\ \text{m}^4}{1,62\ \text{kg/m}}} = 52,3\ \text{Hz} \qquad (16)$$

where

$\gamma = 3,56$ according to IEC 865-1, table 3

$J = 0,5 \cdot 10^{-8}\ \text{m}^4$ (see 4.3.1.1).

The ratio f_c/f is 1,05. From IEC 865-1, figure 4 and 2.2.2.6.2 the following values for the factors V_F, V_σ and V_r are obtained:

$V_F = 1,8$
$V_\sigma = 1,0$
$V_r = 1,0$

4.3.2.2 *Conductor bending stress*

The conductor bending stress is:

$$\sigma_{tot} = \sigma_m = V_\sigma V_r \beta \frac{F_{m3}\, l}{8Z} \qquad (9,12)$$

$$= 1,0 \times 1,0 \times 0,73 \frac{803\ \text{N} \times 1,00\ \text{m}}{8 \times 1 \cdot 10^{-6}\ \text{m}^3} = 73,3 \cdot 10^6\ \text{N/m}^2 = 73,3\ \text{N/mm}^2$$

where

$V_\sigma V_r$ = 1,0 × 1,0 according to 4.3.2.1 above

β = 0,73 according to IEC 865-1, table 3

$Z = 1 \cdot 10^{-6}\ m^3$ (see 4.3.1.1).

The busbars are assumed to withstand the short-circuit force if

$$\sigma_{tot} \le q R_{p0,2} \qquad (13)$$

with the lower value of $R_{p0,2}$. For a rectangular cross-section q = 1,5, see IEC 865-1, table 4. This gives:

$$\sigma_{tot} = 73,3\ N/mm^2 \text{ less than } 1,5 \times 120\ N/mm^2 = 180\ N/mm^2$$

4.3.2.3 *Bending force on the supports*

$$F_d = V_F V_r \alpha F_{m3} \qquad (15)$$

According to 4.3.2.1 above, $V_F V_r$ = 1,8 × 1,0 = 1,8 which is lower than the value 1,97 from IEC 865-1 table 2, see 4.3.1.2.

For the outer supports (A) is with α_A = 0,4, see IEC 865-1, table 3:

$$F_{dA} = V_F V_r \alpha_A F_{m3} = 1,8 \times 1,0 \times 0,4 \times 803\ N = 578\ N$$

For the inner supports (B) is with α_B = 1,1, see IEC 865-1, table 3:

$$F_{dB} = V_F V_r \alpha_B F_{m3} = 1,8 \times 1,0 \times 1,1 \times 803\ N = 1\,590\ N$$

4.3.3 *Conclusions*

		Simplified method	*Detailed method*
The busbars will withstand the short-circuit force.			
The calculated bending stresses σ_{tot} are:	N/mm^2	73,3	73,3
The outer supports have to withstand a dynamic bending force of	N	633	578
The inner supports have to withstand a dynamic bending force of	N	1 740	1 590

5 Example 2 – Mechanical effects on a 10 kV arrangement with multiple rigid conductors

The basis for the calculation in this example is the same three-phase 10 kV busbar as in example 1, but now with three sub-conductors per main conductor as shown in figure 2. The cross-sections of the sub-conductors are 60 mm × 10 mm as the conductors of example 1.

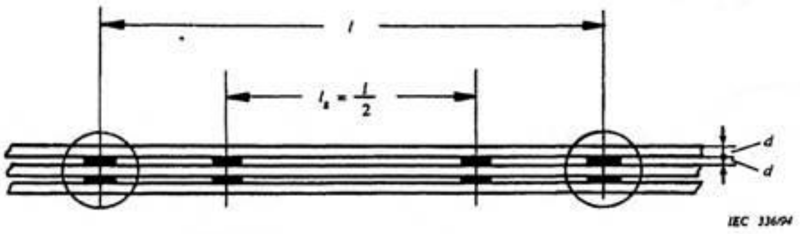


Figure 2 – Position of the spacers and sub-conductors

5.1 *Data (additional to the data of example 1)*

Number of sub-conductors	$n = 3$
Dimension of sub-conductor in the direction of the force	$d = 10$ mm
Number of spacers	$k = 2$
Distance between spacers	$l_s = 0{,}5$ m
Dimension of spacers of AlMgSi0,5	60 mm × 60 mm × 10 mm

5.2 *Maximum force on the central main conductor*

$$F_{m3} = \frac{\mu_0}{2\pi} \frac{\sqrt{3}}{2} i_{p3}^2 \frac{l}{a_m} = \frac{4\pi \cdot 10^{-7}}{2\pi} \frac{\text{Vs}}{\text{Am}} \times \frac{\sqrt{3}}{2} \times (30{,}6 \cdot 10^3 \text{ A})^2 \times \frac{1{,}00 \text{ m}}{0{,}20 \text{ m}} = 811 \text{ N} \quad (2)$$

where

$$i_{p3} = \sqrt{2} \times I''_{k3} = \sqrt{2} \times 1{,}35 \times 16 \text{ kA} = 30{,}6 \text{ kA} = 30{,}6 \cdot 10^3 \text{ A}$$

and the effective distance between the main conductors

$$a_m = \frac{a}{k_{12}} = \frac{0{,}2}{1{,}00} = 0{,}20 \text{ m} \quad (6)$$

with k_{12} according to IEC 865-1 figure 1 for b_m/d_m = 60 mm/50 mm = 1,2 and a/d_m = 200 mm/50 mm = 4. The dimensions b_m and d_m are shown in IEC 865-1, figure 2b.

5.3 *Maximum force on the outer sub-conductor between two adjacent connecting pieces*

$$F_s = \frac{\mu_0}{2\pi}\left(\frac{i_{p3}}{n}\right)^2 \frac{l_s}{a_s} = \frac{4\pi \cdot 10^{-7}}{2\pi}\ \frac{\text{Vs}}{\text{Am}} \times \left(\frac{30{,}6 \cdot 10^3\ \text{A}}{3}\right)^2 \times \frac{0{,}5\ \text{m}}{20{,}2 \cdot 10^{-3}\ \text{m}} = 515\ \text{N} \quad (4)$$

where

$$\frac{1}{a_s} = \frac{k_{12}}{a_{12}} + \frac{k_{13}}{a_{13}} = \frac{0{,}60}{20\ \text{mm}} + \frac{0{,}78}{40\ \text{mm}} = \frac{1}{20{,}2\ \text{mm}} \quad (8)$$

with k_{12} and k_{13} from IEC 865, figure 1:

- $k_{12} = 0{,}60$ for $a_{12}/d = 20$ mm/10 mm = 2 and $b/d = 6$
- $k_{13} = 0{,}78$ for $a_{13}/d = 40$ mm/10 mm = 4 and $b/d = 6$

or a_s from IEC 865-1, table 1.

5.4 *Conductor stress and forces on support*

Calculations can be made according to the following 5.4.1 or according to the following 5.4.2.

5.4.1 *Simplified method*

5.4.1.1 *Bending stress caused by the forces between main conductors*

$$\sigma_m = V_\sigma V_r \beta \frac{F_{m3}\, l}{8Z} \quad (9)$$

$$= 1{,}0 \times 0{,}73 \times \frac{811\ \text{N} \times 1{,}00\ \text{m}}{8 \times 3 \cdot 10^{-6}\ \text{m}^3} = 24{,}7 \cdot 10^6\ \text{N/m}^2 = 24{,}7\ \text{N/mm}^2$$

where

$V_\sigma V_r = 1{,}0 = (V_\sigma V_r)_{max}$ according to IEC 865-1, table 2

$\beta = 0{,}73$ according to IEC 865-1, table 3

$Z = n\,\frac{bd^2}{6} = 3 \times \frac{0{,}06 \times 0{,}01^2}{6}\ \text{m}^3 = 3 \cdot 10^{-6}\ \text{m}^3$ according to IEC 865-1, 2.2.2.3

5.4.1.2 *Bending stress caused by the forces between the sub-conductors*

$$\sigma_s = V_{\sigma s} V_r \frac{F_s\, l_s}{16 Z_s} \quad (10)$$

$$= 1{,}0 \times \frac{515\ \text{N} \times 0{,}5\ \text{m}}{16 \times 1 \cdot 10^{-6}\ \text{m}^3} = 16{,}1 \cdot 10^6\ \text{N/m}^2 = 16{,}1\ \text{N/mm}^2$$

where

$V_{\sigma s} V_r = 1{,}0 = (V_{\sigma s} V_r)_{max}$ according to IEC 865-1, table 2

$Z_s = 1 \cdot 10^{-6}\ \text{m}^3$ as Z in 4.3.1.1 (example 1).

5.4.1.3 *Total bending stress in the busbar material*

$$\sigma_{tot} = \sigma_m + \sigma_s = 24,7 \text{ N/mm}^2 + 16,1 \text{ N/mm}^2 = 40,8 \text{ N/mm}^2 \quad (12)$$

The busbars are assumed to withstand the short-circuit force if

$$\sigma_{tot} \leq q\, R_{p0,2} \quad (13)$$

$$\sigma_s \leq R_{p0,2} \quad (14)$$

with the lower value of $R_{p0,2}$. For a rectangular cross-section $q = 1,5$, see IEC 865-1, table 4 or 2.2.2.3. This gives:

$\sigma_{tot} =$ 40,8 N/mm² less than 1,5 x 120 N/mm² = 180 N/mm²

$\sigma_s =$ 16,1 N/mm² less than 120 N/mm²

5.4.1.4 *Bending force on supports*

$$F_d = V_F\, V_r\, \alpha\, F_{m3} \quad (15)$$

According to IEC 865-1 table 2, with the upper value of $R_{p0,2}$ it is:

$$\frac{\sigma_{tot}}{0,8 \cdot R_{p0,2}} = \frac{40,8 \text{ N/mm}^2}{0,8 \times 180 \text{ N/mm}^2} = 0,283$$

therefore with a three-phase short circuit

$$\frac{\sigma_{tot}}{0,8 \cdot R_{p0,2}} \leq 0,370$$

Hence

$$V_F\, V_r = 2,7$$

For the outer supports (A) is with $\alpha_A = 0,4$, see IEC 865-1, table 3:

$$F_{dA} = 2,7 \times 0,4 \times 811 \text{ N} = 876 \text{ N}$$

For the inner supports (B) is with $\alpha_B = 1,1$, see IEC 865-1, table 3:

$$F_{dB} = 2,7 \times 1,1 \times 811 \text{ N} = 2\,409 \text{ N}$$

5.4.2 *Detailed method*

5.4.2.1 *Natural frequency f_c of the main conductor, f_{cs} of the sub-conductors and factors V_F, V_σ, $V_{\sigma s}$, V_r and V_{rs}*

$$f_c = c\frac{\gamma}{l^2}\sqrt{\frac{EJ_s}{m'_s}} = 0,97 \times \frac{3,56}{(1,00 \text{ m})^2} \times \sqrt{\frac{7 \cdot 10^{10} \text{ N/m}^2 \times 0,5 \cdot 10^{-8} \text{ m}^4}{1,62 \text{ kg/m}}} = 50,8 \text{ Hz} \quad (17)$$

where

$c = 0{,}97$ according to IEC 865-1, figure 3c for $k = 2$ and the ratio

$$\frac{m_z}{n\,m'_s\,l} = \frac{1{,}62 \text{ kg/m} \times 0{,}06 \text{ m} \times 2}{3 \times 1{,}62 \text{ kg/m} \times 1{,}00 \text{ m}} = 0{,}04$$

$\gamma = 3{,}56$ from IEC 865-1, table 3

$J = 0{,}5 \cdot 10^{-8}\text{ m}^4$ as J in example 1.

$$f_{cs} = \frac{3{,}56}{l_s^2}\sqrt{\frac{EJ_s}{m'_s}} = \frac{3{,}56}{(0{,}5\text{ m})^2} \times \sqrt{\frac{7 \cdot 10^{10}\text{ N/m}^2 \times 0{,}5 \cdot 10^{-8}\text{ m}^4}{1{,}62\text{ kg/m}}} = 209\text{ Hz} \qquad (18)$$

The ratio f_c/f is 1,02 and f_{cs}/f is 4,18. This gives from IEC 865-1, figure 4 and 2.2.2.6.2 the following values to the factors V_F, V_σ, $V_{\sigma s}$, V_r and V_{rs}:

$V_F = 1{,}8$
$V_\sigma = 1{,}0$
$V_{\sigma s} = 1{,}0$
$V_r = 1{,}0$
$V_{rs} = 1{,}0$

5.4.2.2 *Bending stress caused by the forces between main conductors*

$$\sigma_m = V_\sigma V_r \beta \frac{F_{m3}\,l}{8Z} \qquad (9)$$

$$= 1{,}0 \times 1{,}0 \times 0{,}73 \times \frac{811\text{ N} \times 1{,}00\text{ m}}{8 \times 3 \cdot 10^{-6}\text{ m}^3} = 24{,}7 \cdot 10^6\text{ N/m}^2 = 24{,}7\text{ N/mm}^2$$

where

$V_\sigma V_r = 1{,}0 \times 1{,}0$ according to 5.4.2.1 above

$\beta = 0{,}73$ according to IEC 865-1, table 3

$Z = n\dfrac{bd^2}{6} = 3 \times \dfrac{0{,}06 \times 0{,}01^2}{6}\text{ m}^3 = 3 \cdot 10^{-6}\text{ m}^3$ according to IEC 865-1, 2.2.2.3

5.4.2.3 *Bending stress caused by the forces between the sub-conductors*

$$\sigma_s = V_{\sigma s} V_{rs} \frac{F_s\,l_s}{16Z_s} \qquad (10)$$

$$= 1{,}0 \times 1{,}0 \times \frac{515\text{ N} \times 0{,}5\text{ m}}{16 \times 1 \cdot 10^{-6}\text{ m}^3} = 16{,}1 \cdot 10^6\text{ N/m}^2 = 16{,}1\text{ N/mm}^2$$

where

$V_{\sigma s} V_{rs} = 1{,}0 \times 1{,}0$ according to 865-1, table 2

$Z_s = 1 \cdot 10^{-6}\text{ m}^3$ as Z in 4.3.1.1 (example 1)

5.4.2.4 *Total bending stress in the busbar material*

$$\sigma_{tot} = \sigma_m + \sigma_s = 24{,}7 \text{ N/mm}^2 + 16{,}1 \text{ N/mm}^2 = 40{,}8 \text{ N/mm}^2 \quad (12)$$

The busbar is assumed to withstand the short-circuit force if

$$\sigma_{tot} \le q\, R_{p0,2} \quad (13)$$

$$\sigma_s \le R_{p0,2} \quad (14)$$

with the lower value of $R_{p0,2}$. For a rectangular cross-section q = 1,5, see IEC 865-1, table 4. This gives:

σ_{tot} = 40,8 N/mm² less than 1,5 × 120 N/mm² = 180 N/mm²
σ_s = 16,1 N/mm² less than 120 N/mm²

5.4.2.5 *Bending force on the supports*

$$F_d = V_F V_r \alpha F_{m3} \quad (15)$$

According to 5.4.2.1 above, $V_F V_r$ = 1,8 × 1,0 = 1,8 which is lower than the value 2,7 obtained from IEC 865-1, table 2 in the case of the simplified method, see 5.4.1.4.

For the outer supports (A) is with α_A = 0,4, see IEC 865-1, table 3:

$$F_{dA} = V_F V_r \alpha_A F_{m3} = 1{,}8 \times 1{,}0 \times 0{,}4 \times 811 \text{ N} = 584 \text{ N}$$

For the inner supports (B) is with α_B = 1,1, see IEC 865-1, table 3:

$$F_{dB} = V_F V_r \alpha_B F_{m3} = 1{,}8 \times 1{,}0 \times 1{,}1 \times 811 \text{ N} = 1\,606 \text{ N}$$

5.4.3 *Conclusions*

			Simplified method	*Detailed method*
The busbars will withstand the short-circuit force.				
The calculated bending stresses are	σ_{tot}	N/mm²	40,8	40,8
	σ_s	N/mm²	16,1	16,1
The outer supports have to withstand a dynamic bending force of		N	876	584
The inner supports have to withstand a dynamic bending force of		N	2 409	1 606

13. Annex D – COMPARISON WITH TEST REPORTS.

REPORT 19901/009-C – SHORT-TIME WITHSTAND CURRENT AND PEAK WITHSTAND CURRENT TESTS

19901/09-C

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tabela de ensaios realizados

data	tipo de ensaio	página nº
03/06/2009	Ensaios de verificação de funcionamento mecânico.	05
03/06/2009	Ensaio de verificação da corrente suportável de curto-circuito nos barramentos.	06
04/06/2009	Ensaios de verificação da corrente suportável de curto-circuito nos circuitos de saída.	07 e 08
04/06/2009	Ensaio de verificação da corrente suportável de curto-circuito no barramento de neutro.	09
05/06/2009	Ensaios de verificação da eficácia do circuito de proteção.	10 e 11

Pág. nº: 06 **de** 82

ensaio de verificação da corrente suportável de curto-circuito nos barramentos

condições do circuito de ensaio

circuito de ensaio - pág. 13 **fator de potência** 0,20 **freqüência** 60 Hz

arranjo de ensaio: ver fotos 1 e 2 - página 19.

condições do equipamento antes do ensaio: como após os ensaios anteriores.

ensaio	oscilograma	duração	corrente de ensaio: valor de crista máximo	corrente de ensaio: valor eficaz simétrico	notas
nº	nº	s	kA	kA	
			102,7	65,1	
4	275/09	1,0	126,0	65,4	1) Ensaio nº 4 realizado no circuito descrito na observação nº 1 nas colunas 1 (toda), 2 (parte) e 3 (toda).
			143,7	66,4	
				média=65,6	2) Os barramentos de interligação e vertical da coluna 2 não foram submetidos a este tipo de ensaio porque o de interligação (1 barra de cobre prateada por fase de 2"x3/8") era idêntico ao da coluna 3 e o vertical (1 barra de cobre prateada por fase de 3"x1/4"com 11 isoladores tipo pente) era similar ao da coluna 3 (1 barra de cobre nu por fase de 3"x1/4"com 10 isoladores tipo pente).

condições do equipamento após o ensaio: sem anormalidades.

REPORT 67752 – TEMPERATURE RISE TEST

67752 - Calentamiento

UNIVERSIDADE DE SÃO PAULO
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FOLHA 1 de 3

RELATÓRIO OFICIAL Nº: 67752

Um painel de baixa tensão de fabricação [redacted] conforme desenho anexo 16.09.10225, fl. 27/29 e 28/29, rev. A, de 18/05/09, fornecido pelo Interessado.

[redacted]

OBJETIVO: 1) Ensaio de elevação de temperatura, em 60 Hz

OBSERVAÇÕES: a) Registrado sob a OS 2009882E;
b) Data de realização do ensaio: 22/05/2009;
c) Este relatório foi emitido em (02) duas vias de igual teor.

1. Ensaio de elevação de temperatura, em 60 Hz

1.1 Condições de ensaio:

O ensaio foi realizado de acordo com o item 6.5 da norma NBR IEC 62271-200, de 19/04/2007, da ABNT.

1.2 Procedimentos adotados:

1.2.1 O ensaio foi realizado fazendo-se circular nas três fases do circuito principal do corpo de prova, a corrente trifásica de ensaio de 3200A, especificada pelo Interessado, em 60 Hz, até ocorrer a estabilização das elevações de temperatura nos pontos de medição, durante (01) uma hora.

1.2.2 O ensaio foi realizado com o sistema de exaustão ligado.

1.2.3 Foram colocadas lâmpadas incandescentes no interior do invólucro afim de simular a potência total dissipada pelos acessórios, e com os valores indicados em desenho anexo mencionado anteriormente.

1.2.4 Para a alimentação foram utilizados barramentos de cobre nu (dois por fase) de dimensões aproximadas de (10x125x2900)mm.

67752 - Calentamiento

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FOLHA
2 de 3

RELATÓRIO OFICIAL Nº: 67752

1.3 Pontos de medição:

Indicados pelo Interessado em desenho anexo, citado anteriormente e descritos pelo mesmo como:

P1 – a 1000mm da conexão de entrada do painel, fase S;
P2 – conexão barramento vertical e cabos, fase S – coluna 1;
P3 - conexão barramento vertical e barramento de entrada – coluna 1;
P4 - conexão inferior do disjuntor e barramento vertical, fase R – coluna 1;
P5 – conexão inferior do disjuntor e barramento vertical, fase S – coluna 1;
P6 - conexão inferior do disjuntor e barramento vertical, fase T – coluna 1;
P7 - conexão superior do disjuntor e barramento vertical, fase R – coluna 1;
P8 – conexão superior do disjuntor e barramento vertical, fase S – coluna 1;
P9 - conexão superior do disjuntor e barramento vertical, fase T – coluna 1;
P10 - conexão barramento vertical e horizontal, fase R – coluna 1;
P11 – conexão barramento vertical e horizontal, fase S – coluna 1;
P12 - conexão barramento vertical e horizontal, fase T – coluna 1;
P13 – barramento, fase R – coluna 2;
P14 – barramento, fase S – coluna 2;
P15 - barramento, fase T – coluna 2;
P16 – no fechamento "estrela";
P17 – ambiente interno – coluna 1;
P18 – ambiente interno – coluna 2;
P19 – porta.

67752 - Calentamiento

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RELATÓRIO OFICIAL Nº: 67752

1.4 Resultados obtidos :

- Corrente trifásica de ensaio : 3200A
- Temperatura ambiente (Ta) : 23°C
- Temperaturas finais (T) e máximas elevações de temperatura (T – Ta)

PONTOS DE MEDIÇÃO	T (°C)	T-Ta (°C)
P1	54	31
P2	69	46
P3	76	53
P4	95	72
P5	102	79
P6	97	74
P7	105	82
P8	115	92
P9	110	87
P10	84	61
P11	99	76
P12	97	74
P13	53	30
P14	64	41
P15	63	40
P16	69	46
P17	55	32
P18	36	13
P19	31	8

2.5 Observação:

[redacted]

* * * * *

São Paulo, 15 de julho de 2009.

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RELATÓRIO OFICIAL Nº: 65111

Um painel de média tensão de fabricação [redacted] conforme desenhos anexos 26.08.9278, fls. 02, 03 e 04, rev. D, de 28/03/08, fornecidos pelo Interessado.

INTERESSADO: [redacted]

OBJETIVOS: 1) Medição da resistência ôhmica dos barramentos do circuito principal
2) Ensaio de elevação de temperatura, em 60 Hz

OBSERVAÇÕES: a) Registrado sob a OS 2008364E;
b) Data de realização do ensaio: 18/04/2008;
c) Este relatório foi emitido em (02) duas vias de igual teor.

1. Medição da resistência ôhmica dos barramentos do circuito principal

1.1 Condições de ensaio:

O ensaio foi realizado tomando-se como referência o item 6.4 da norma NBR IEC 62271-200, de 19/04/2007, da ABNT.

1.2 Resultados obtidos:

- anterior ao ensaio de elevação de temperatura:

corrente de ensaio: 100 A ; temperatura ambiente: 22°C

fase R : 112 μΩ ; fase S : 116 μΩ ; fase T : 122 μΩ

- posterior ao ensaio de elevação de temperatura:

corrente de ensaio: 100 A ; temperatura ambiente: 21°C

fase R : 111 μΩ ; fase S : 116 μΩ ; fase T : R = 122 μΩ

RELATÓRIO OFICIAL Nº: 65111

2. Ensaio de elevação de temperatura, em 60 Hz

2.1 Condições de ensaio:

O ensaio foi realizado de acordo com o item 6.5 da norma NBR IEC 62271-200, de 19/04/2007, da ABNT.

2.2 Procedimentos adotados:

O ensaio foi realizado fazendo-se circular nas três fases do circuito principal, conectadas em "estrela", a pedido do Interessado, a corrente trifásica de ensaio de 1250 A, em 60 Hz, até ocorrer a estabilização das elevações de temperatura nos pontos de medição, durante (01) uma hora.

2.3 Pontos de medição:

Indicados pelo Interessado em desenho anexo, citado anteriormente e descritos pelo mesmo como:

P1 – a 1000mm da conexão de entrada do painel, fase S;
P2 – conexão de entrada do barramento externo do cubículo, próximo ao parafuso, fase R;
P3 - conexão de entrada do barramento externo do cubículo, próximo ao parafuso, fase S;
P4 - conexão de entrada do barramento externo do cubículo, próximo ao parafuso, fase T;
P5 – conexões entre barras internas da fase R do cubículo, próximo ao parafuso, fase R;
P6 - conexões entre barras internas da fase S do cubículo, próximo ao parafuso, fase S;
P7 - conexões entre barras internas da fase T do cubículo, próximo ao parafuso, fase T;
P8 – barra R, ponto de conexão com a tulipa, entrada do disjuntor;
P9 - barra S, ponto de conexão com a tulipa, entrada do disjuntor;
P10 - barra T, ponto de conexão com a tulipa, entrada do disjuntor;
P11 – pinça R do disjuntor, conexão interna da tulipa (entrada);
P12 - pinça S do disjuntor, conexão interna da tulipa (entrada);
P13 - pinça T do disjuntor, conexão interna da tulipa (entrada);
P14 - pinça R do disjuntor, conexão interna da tulipa (saída);
P15 - pinça S do disjuntor, conexão interna da tulipa (saída);
P16 - pinça T do disjuntor, conexão interna da tulipa (saída);
P17 – barra R, ponto de conexão com a tulipa, saída do disjuntor;
P18 - barra S, ponto de conexão com a tulipa, saída do disjuntor;
P19 - barra T, ponto de conexão com a tulipa, saída do disjuntor;
P20 – no fechamento estrela;
P21 – frontal da porta do compartimento do disjuntor;
P22 – maçaneta da porta do compartimento do disjuntor.

RELATÓRIO OFICIAL Nº: 65111

2.4 Resultados obtidos :

- Corrente trifásica de ensaio : 1250A
- Temperatura ambiente (Ta) : 23°C
- Temperaturas finais (T) e máximas elevações de temperatura (T – Ta)

PONTOS DE MEDIÇÃO	T (°C)	T-Ta (°C)
P1	58	35
P2	58	35
P3	57	34
P4	54	31
P5	64	41
P6	67	44
P7	68	45
P8	75	52
P9	79	56
P10	79	56
P11	88	65
P12	95	72
P13	90	67
P14	86	63
P15	91	68
P16	87	64
P17	77	54
P18	77	54
P19	78	55
P20	62	39
P21	35	12
P22	30	7

67131 - Calentamiento

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FOLHA

RELATÓRIO OFICIAL Nº: 67131

Um barramento trifásico denominado pelo Interessado como: [redacted] TRI+T", de fabricação [redacted] conforme desenho N.OP.: 08248-00, rev.03 de 25/03/09, em anexo, fornecido pelo mesmo.

INTERESSADO: [redacted]

OBJETIVO: Ensaio de elevação de temperatura, em 60 Hz

OBSERVAÇÕES: a) Registrado sob a OS 2009411;
b) Data de realização do ensaio: 24/03/2009;
c) Este relatório foi emitido em (02) duas vias de igual teor.

1. Ensaio de elevação de temperatura, em 60Hz

1.1 Condições de ensaio:

O ensaio foi realizado de acordo com o item 8.2.1 da norma NBR IEC 60439-2, de agosto de 2007.

1.2 Procedimentos adotados:

O ensaio foi realizado fazendo-se circular nas três fases do corpo de prova, conectadas em estrela, a corrente trifásica de ensaio de 4000A, especificada pelo Interessado.

1.3 Pontos de medição:

Indicados e descritos pelo Interessado conforme desenho anexo, citado anteriormente.

67131 - Calentamiento

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RELATÓRIO OFICIAL Nº: 67131

1.4 Resultados obtidos:

- Corrente trifásica de ensaio: 4000 A
- Temperatura ambiente (Ta): 26,8°C
- Temperaturas finais (T) e máximas elevações de temperatura (T – Ta)

PONTOS DE MEDIÇÃO	T (°C)	T-Ta (°C)
P1	92	65,2
P2	99,2	72,4
P3	92,7	65,9
P4	104	77,2
P5	111,5	84,7
P6	105	78,2
P7	104,9	78,1
P8	110,3	83,5
P9	106,4	79,6
P10	104,8	78
P11	110,7	83,9
P12	106	79,2
P13	93,4	66,6
P14	57	30,2
P15	57,9	31,1

Informe 08-050 – Arco Interno

zkratovna
Zkušebnictví, a.s.

Report No.: 08 – 050
Sheet: 7/27

1. Table of test results: Arcing due to an internal fault test

Test circuit diagram: ROV331
File denomination: rozv13eu, rozv16eu

Test No.	U_a (kV)	I_m (kA)	I_{3c} (kA)	I_1 (kA)	I_2 (kA)	I_e (kA)	t_i (ms)	p_{max} (kPa)	Note
rozv13eu 005	13,6	82,1 68,8 64,9	37,1 37,3 35,9	35,0 35,3 34,3	30,2 30,7 30,0	32,6 32,8 32,0	1030	---	Calibration of the test circuit
006	13,8	81,6 65,7 66,0	37,3 36,2 36,4	35,4 35,1 35,0	30,6 30,9 29,0	32,5 32,2 32,1	1030	---	**Cable compartment** [1)]
rozv16eu 003	13,7	79,4 63,5 65,8	37,0 36,8 34,8	34,7 35,1 34,1	30,2 30,6 29,9	32,2 32,5 31,9	1030	51,9	**Circuit breaker compartment**
004	13,7	78,9 61,8 66,4	36,7 36,5 34,5	34,6 34,9 34,1	30,0 30,1 29,7	32,2 32,3 31,7	1030	---	**Bus-bars compartment**

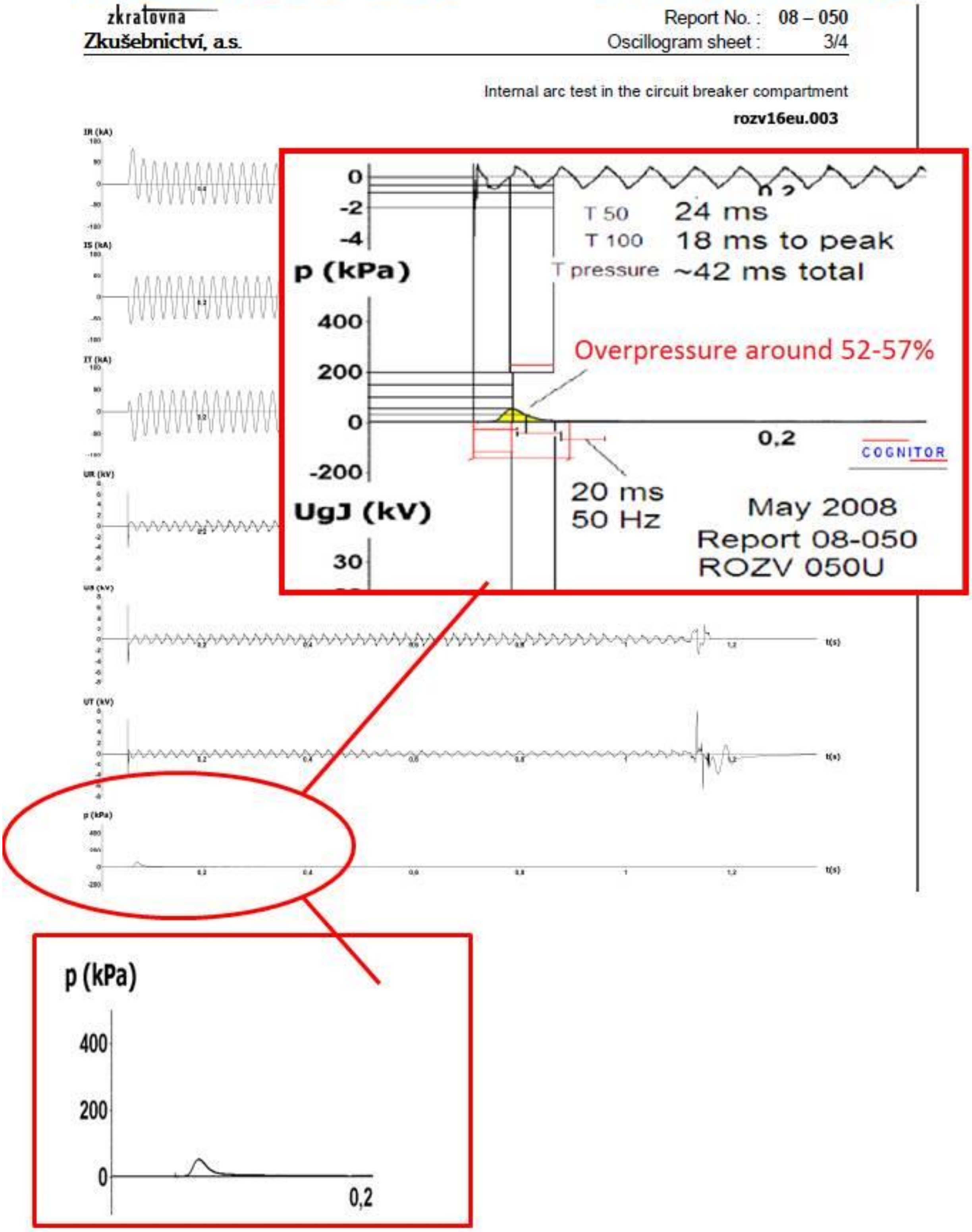
1) Two indicators were burnt after the test termination (ca 0,5 s after the end of test). It is visible and verified on the video record of a high speed camera (see enclosed DVD).

Conclusion: the switchgear passed successfully the test in the cable compartment.

Assessment according to criteria IEC 62271 - 200: 2003 Annex A / A.6 for IAC - A (for all tested compartments)

Criterion after test	**Assessment Commentary**
Criterion No.1 / no opened door, deformation of the covers /	**MET** No doors opened any significant deformation.
Criterion No.2 / no flown off fragments /	**MET** No fragmentation of the enclosure occurred except for sparking.
Criterion No.3 / no holes in accessible parts /	**MET** Arcing didn't cause holes in the enclosure.
Criterion No.4 / no burned indicators /	**MET** No indicators ignited.
Criterion No.5 / no disconnection, the enclosure remained connected to its earthing point /	**MET** Visual inspection checked that the enclosure remained connected to its earthing point.

Informe 08-050 – Arco Interno



14. Annex E – INFORMATION ABOUT A CIGRE BROCHURE ABOUT INTERNAL ARC WHICH WILL BE PUBLISHED IN 2014.

Brochure Cigrè to be published 2014

TOOLS FOR THE SIMULATION OF THE EFFECTS OF THE INTERNAL ARC IN TRANSMISSION AND DISTRIBUTION SWITCHGEAR

WG A3.24

Members

N. Uzelac, **Convenor** (US) M. Glinkowski, **Secretary** (US), L. del Rio (ES), M. Kriegel, **Former Convenor** (CH), J. Douchin (FR), E. Dullni (DE), S. Feitoza Costa (BR), E. Fjeld (NO), H-K. Kim (KR), J. Lopez-Roldan (AU), R. Pater (CA), G. Pietsch (DE), T. Reiher (DE), G. Schoonenberg (NL), S. Singh (DE), R. Smeets (NL), T. Uchii (JP), L. Van der Sluis (NL), P. Vinson (FR), D. Yoshida (JP)

ISBN : (To be completed by CIGRE)

TABLE OF CONTENTS

Brochure Cigre to be published 2014

2.5.3 MV switchgear with air insulation

Case No.	A	B	C	D	
Volume of arc comp. (V_1)	0.509	0.509	0.648	0.27	m³
Volume of exhaust comp. (V_2)	>1000	1.275	>1000	0.58	m³
Volume of installation room (V_3)	n/a	>1000	n/a	>1000	m³
Initial pressure in V_1	150	160	100	120	kPa abs air
Initial pressure in V_2	100	100	100	100	kPa abs air
Area of the relief opening A_{12}	0.00456	0.00456	0.0763	0.049	m²
Discharge coefficient of A_{12}	0.7	1.0	0.7	1.0	
Response pressure of relief device	276	285	35,3	220	kPa rel
Area of the opening A_{23}	0	0.010	0	0.195	m²
Short-circuit current	14.5	14.5	14.5	38.8	kA rms
Number of phases	1	1	2	3	
Averaged phase-to-ground voltage	314	424	400	250	V
k_p-factor	0.4	0.55	0.7	0.6	

Table 2-3: Input parameters and initial values for MV switchgear cases with air insulation.

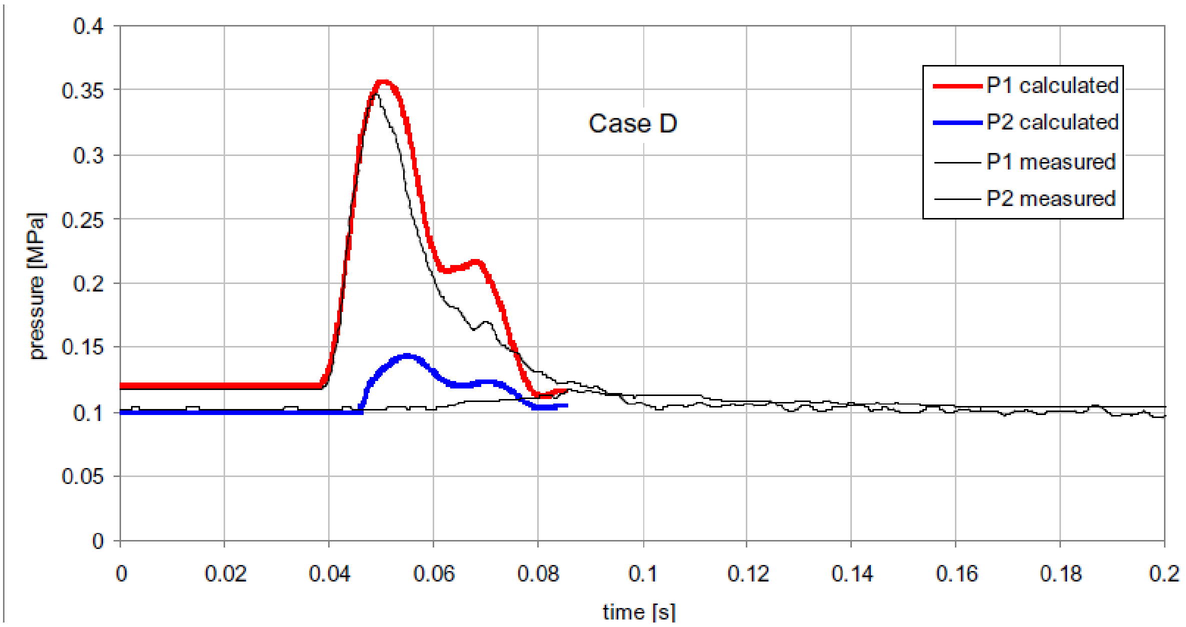
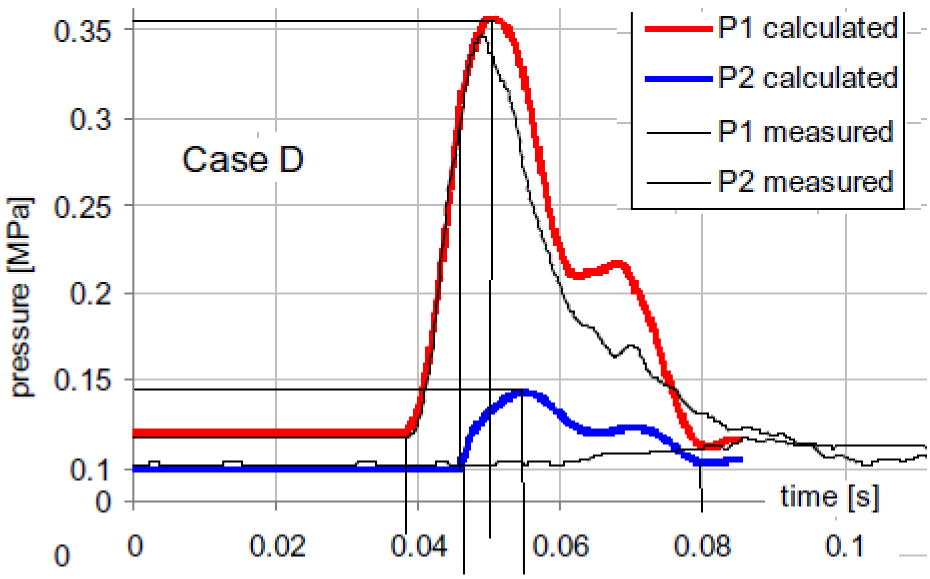


Figure 2-13: Case D – Calculated pressure developments in V_1 and V_2 with air as filling gas and comparison with test.



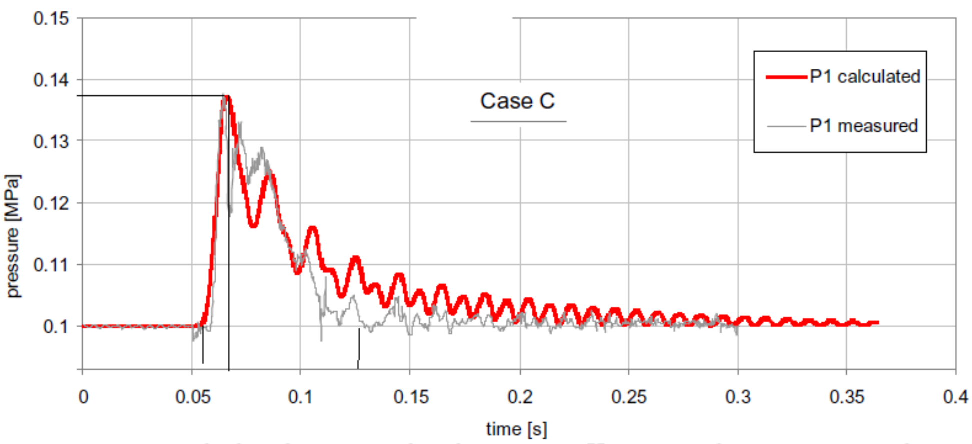


Figure 2-12: Case C – Calculated pressure development in V_1 in air and comparison with test.

15. Annex F- INFORMATION ABOUT DE NEW IEC 62271-307 IN PREPARATION.

IEC/TR 62271-307: High-voltage switchgear and controlgear - Part 307: Guidance for the extension of validity of type tests of AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV.

Estas informaciones no sin aun confirmadas – están en estudios

DRAFT NOT OFFICIAL – NOT APPROVED – IN STUDIES

3rd CD 2014-03-10 - WG 31 © IEC:201X – 1 IEC/TR 62271-307

INTERNATIONAL ELECTROTECHNICAL COMMISSION

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 307: Guidance for the extension of validity of type tests of AC metal and solid-insulation enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV

FOREWORD

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IEC/TR 62271-307, which is a technical report, has been prepared by subcommittee 17C: HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR ASSEMBLIES, of IEC technical committee 17: SWITCHGEAR AND CONTROLGEAR

This Technical Report is to be read in conjunction with IEC 62271-200 Ed.2 published in 2011 and IEC 62271-201 Ed.2 published in 2014.

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Table 3– Extension criteria for temperature rise performance

Item	Design parameter	Acceptance criterion	Condition
(1)	(2)	(3)	(4)
1	Centre distance between phases	≥	Only to be validated for rated normal currents above 1250 A (see IEC 62271-1:2011 clause 6.5.2)
2	Phase to earth distance	≥	Only to be validated if an influence on the surrounding elements due to currents cannot be excluded, e.g. eddy currents and magnetising currents. Note 1
3	Enclosure/compartment dimensions (L,H,W) and volume	≥	The enclosure and compartments are of the same construction. Note 1
4	Minimum pressure of insulating gas	≥	Same gas; for gas insulated switchgear
5	Current density of conductors	≤	The conductors have the same physical arrangement
6	Resistance per unit length of conductors	≤	Compare conductor material and cross-section
7	Contact surface area of connections / joints	≥	Same or better contact material
8	Contact force of connections / joints	≥	Same or better contact material
9	Permissible temperature of contact materials of connections / joints	≥	Including metallic coatings having the same or lower resistivity
10	Effective ventilation area of partitions and enclosure	≥	Note 2
11	Power dissipation of components	≤	Here the main switching devices, fuses and current transformers are considered. Note 3
12	Area of insulating barriers	≤	Barriers have the same physical arrangement
	Thickness of insulating coating of conductors	≤	Thermal resistivity and emission coefficient should be the same. Note 4
	Coated surface area of enclosure for heat transfer	≥	The emission coefficient of the coating should be the same.
	Temperature class of insulating material in contact with conductors	≥	

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Table 5– Extension criteria for short-time and peak withstand current performance

Item	Design parameter	Acceptance criterion	Condition
(1)	(2)	(3)	(4)
1	Centre distance between phases	≥	
2	Electro-dynamic forces due to current path	≤	The conductors have the same physical arrangement. Note 1
3	Mechanical strength of insulating conductor supports	≥	Notes 2 and 3
4	Length of unsupported sections of conductors	≤	
5	Cross-section of conductors	≥	Connections of the conductors are scaled and have the same or greater clamping force and contact area.
6	Material of conductors	same	
7	Temperature class of insulating material in contact with conductors	≥	
8	Mechanical strength of the enclosure /partitions/ bushings	≥	Notes 2 and 3
9	Contacts of removable part	Same	Consider complete design of contact sub-assembly and the fixing / mounting of the removable part.

Note 1: The effect of different paths might be assessed by calculation of electro-dynamic forces

Note 2: Strength includes mechanical resistance to compression, traction, and bending loads.

Note 3: The enclosure may provide the base for the mechanical supports.

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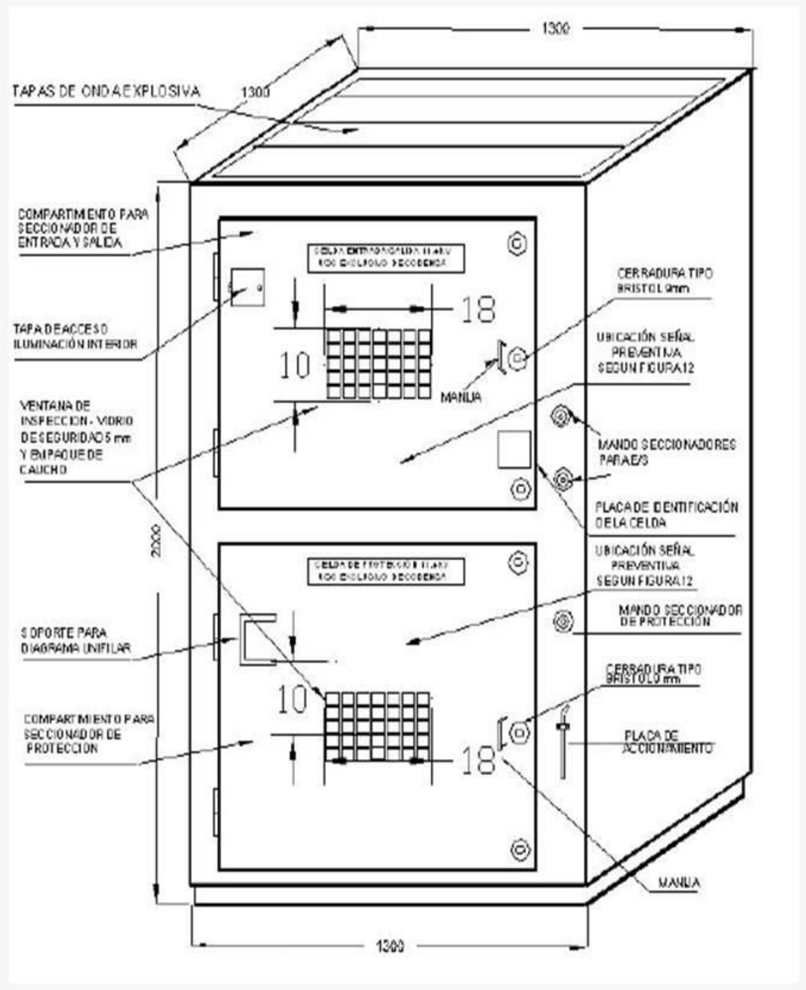
Table 7– Extension criteria for internal arc fault withstand performance

Item	Design parameter	Acceptance criterion	Condition
(1)	(2)	(3)	(4)
1	Clearance between phases	≤	
2	Clearance to earth	same	This concerns the region where the arc is initiated.
3	Net compartment volume	≥	
4	Rated pressure of insulating gas, if applicable; see note 1	≤	
5	Cross-section of conductors	≥	This concerns the region where the arc is initiated.
6	Raw material of conductors (Al or Cu or their alloys)	same	This concerns the region where the arc is initiated.
7	location of the point of arc initiation	same	Applying the rules of IEC 62271-200 or IEC 62271-201
8	Insulating material exposed to the arc	same	
9	Exhaust cross sectional area	≥	The position of the exhaust in the compartment and the gas flow path are the same. Larger cross sectional areas are only acceptable, if an exhaust duct is used
10	Exhaust opening pressure	≤	Applicable to fluid tight compartments
11	Mechanical strength of elements to let open the relief device (flap)	≤	Applicable to non-tight compartments. The relief device and its retaining elements have the same design.
12	Mechanical strength of the enclosure and compartment	≥	This also includes the strength of partitions and bushings Note 2
13	Thickness of the enclosure walls	≥	Same material Note 2
14	Mechanical strength of the doors and covers	≥	Note 2
15	Degree of protection (IP-code) of enclosure	≥	Where relevant for indicator ignition criterion

16. Annex G- CELDA ET 651.



CELDA DE TRIPLEX PARA ENTRADA SALIDA Y PROTECCIÓN (VISTA ISOMETRICA)

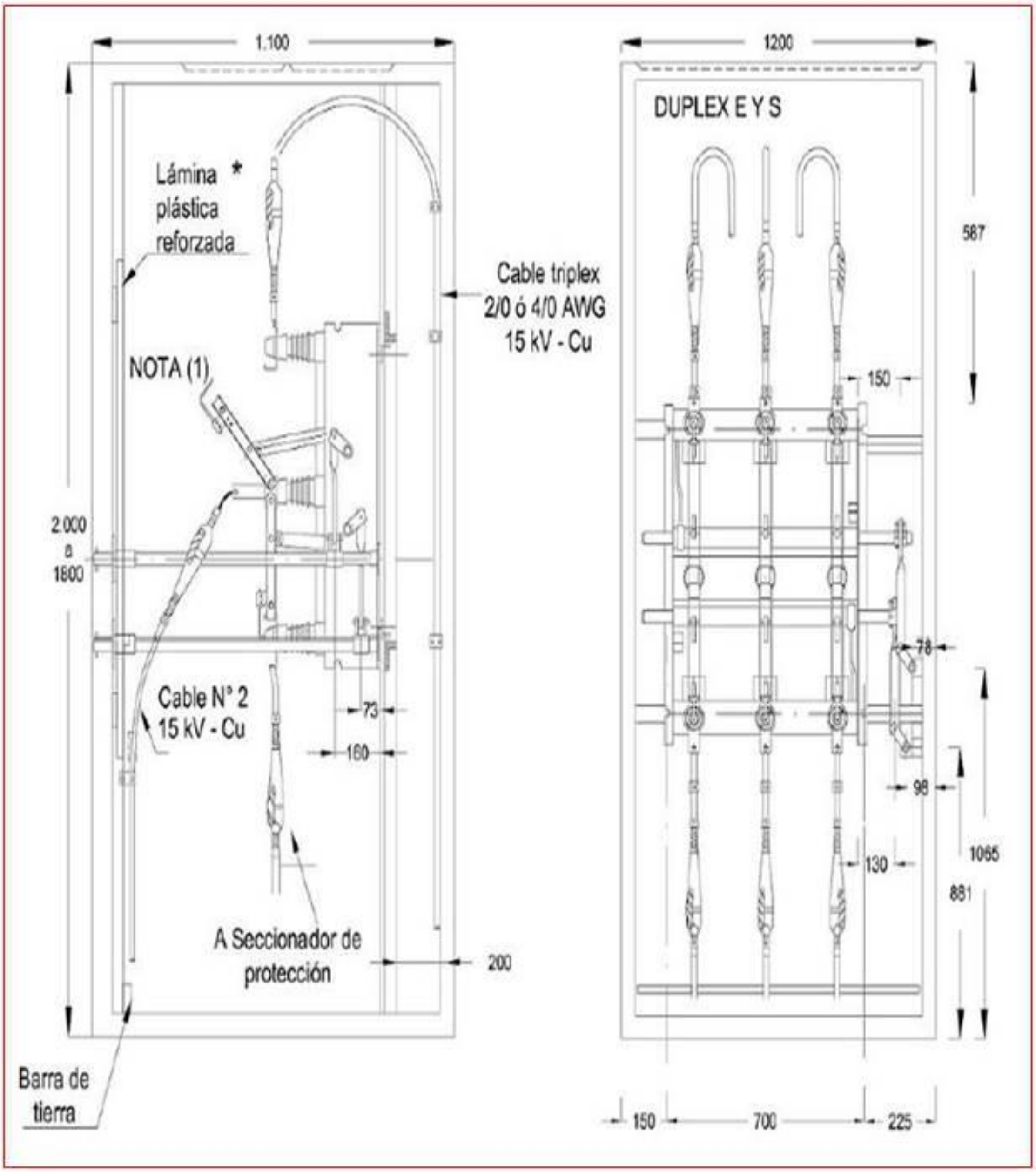

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Lámina *
plástica
reforzada
Cable triplex
2/0 ó 4/0 AWG
15 kV - Cu
NOTA (1)
587
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1800
78
Cable N° 2
15 kV - Cu
73
160
98
130
1065
881
A Seccionador de
protección
200
Barra de
tierra
150
700
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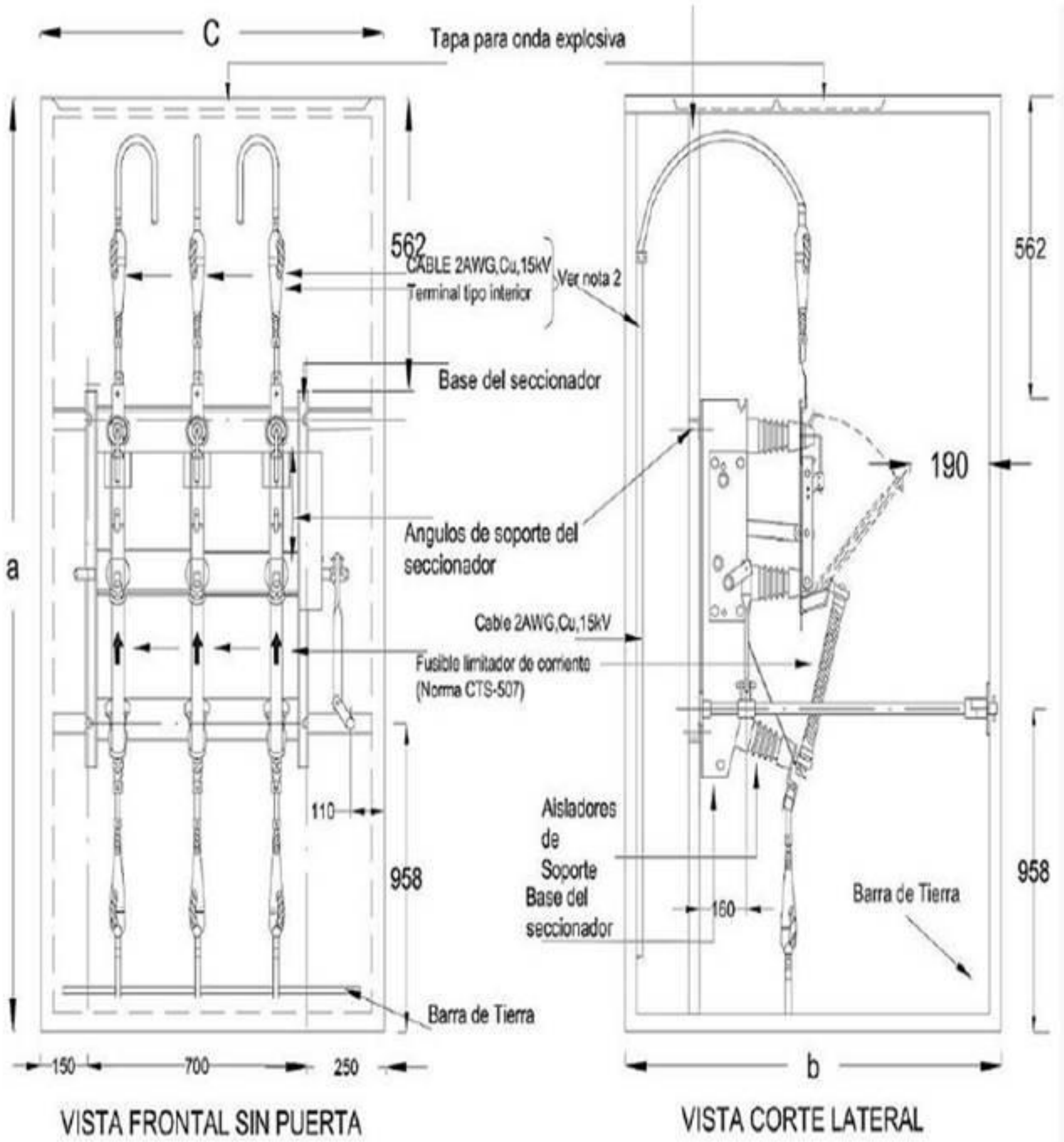
C
Tapa para onda explosiva
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Base del seccionador
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Fusible limitador de corriente
(Norma CTS-507)
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958
Barra de Tierra
150
700
250
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Aisladores de Soporte
Base del seccionador
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Barra de Tierra
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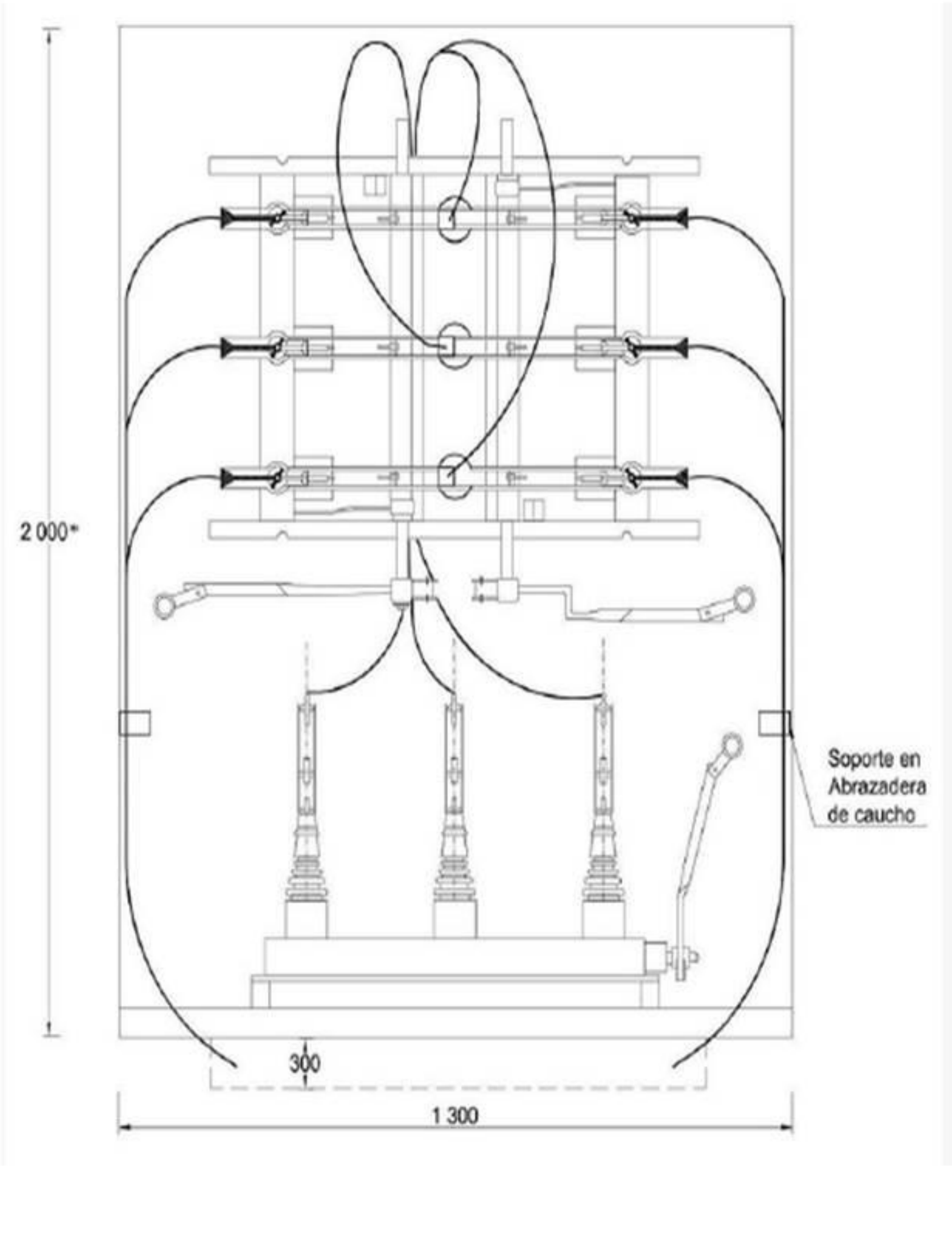
b
VISTA CORTE LATERAL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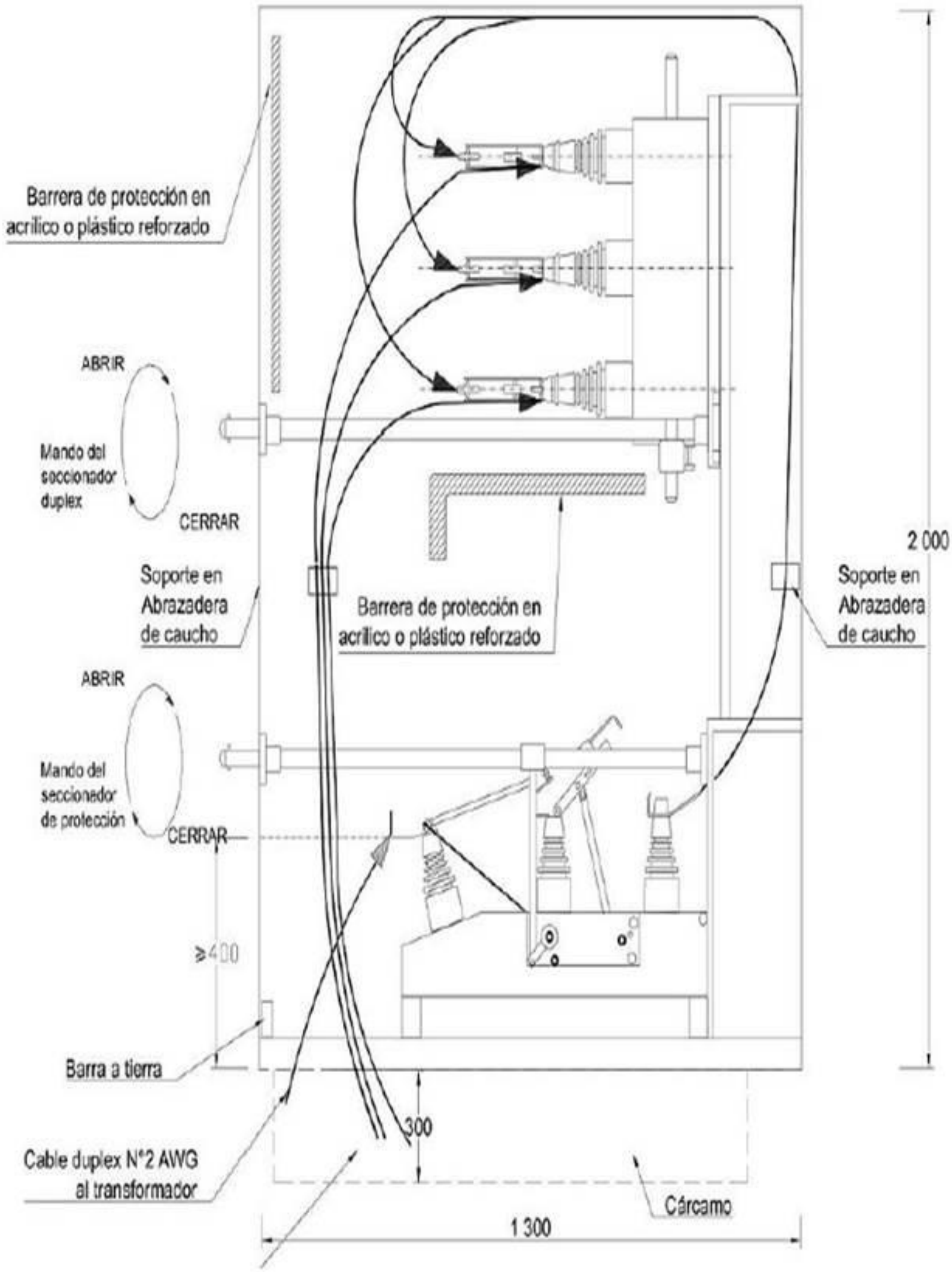
Soporte en
Abrazadera
de caucho
300
1 300



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acrílico o plástico reforzado
ABRIR
Mando del
seccionador
duplex
CERRAR
Soporte en
Abrazadera
de caucho
Barrera de protección en
acrílico o plástico reforzado
Soporte en
Abrazadera
de caucho
2 000
ABRIR
Mando del
seccionador
de protección
CERRAR
≥400
Barra a tierra
Cable duplex N°2 AWG
al transformador
300
Cárcamo
1 300