TEST SIMULATION REPORT 074/2015

http://www.cognitor.com.br/TR074ENGValidationTempRise.pdf

TITLE	VALIDATION OF **MAGNETIC & ELECTRIC FIELDS MAPPING & TEMPERATURE RISE TESTS SIMULATIONS.**
	With the software Switchgear_Design (internal arc tests, electrodynamic forces, short time current and peak withstand tests, temperature rise tests, magnetic and electric fields mapping)
Application	Document for use in the training "In Company" entitled "ENGINEERING AND DESIGN CONCEPTS + software for SUBSTATIONS AND EQUIPMENT FOR SUBSTATIONS". (for certification and testing companies, manufacturers of switchboards, switchgear, busbar systems and other equipment for substations),
REFERENCE IEC 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 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 IEC 61439 - Low-voltage switchgear and controlgear assemblies.
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Revisions	Date	Pages	Description
0	June, 15 , 2015	-	First version
1	August, 21 , 2015		Included electric and magnetic fields
2	September, 20, 2016		Small editorial corrections

CONTENTS

1. INTRODUCTION

This document intends to help the users of the software SwitchgearDesign who need to do validations of their simulations. Such validations are used to prove, transparently, that the simulation results are within an acceptable tolerance from the values of the actual results obtained in the laboratory tests. Table 1 present values of acceptable tolerances (see Annex F) considered in this text. These values as well as a "technical standard" for the proper use of simulations are detailed in Annex F. An IEC technical standard is missing on this theme and this text may be used freely, by anyone, as a reference for this purpose.

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%
Magnetic and electrical field mapping	Module and XYZ components of the field at any point	5%

This report is applicable to magnetic & electric fields mapping and temperature rise tests simulations. It complements another one, from November 2014, including also simulations of internal arc tests and short time current (electro dynamical forces) tests
(Free download in http://www.cognitor.com.br/TR_071_ENG_ValidationSwitchgear.pdf)

The new information in report is the inclusion of more test cases for temperature rise simulations and the addition of the capability of mapping electric and magnetic fields.
(Free download in http://www.cognitor.com.br/TR074ENGValidationTempRise.pdf)

Both reports were prepared for use in the training course applied by Cognitor entitled "ENGINEERING AND DESIGN CONCEPTS + software for SUBSTATIONS AND EQUIPMENT FOR SUBSTATIONS". This training is handmade for manufacturers of high to low voltage equipment as well as certification companies and testing laboratories. It is applied all over the World and useful for whom want to know sound engineering design concepts and to apply them in equipment design using the software SwitchgearDesign.

The participants receive and learn how to use this software developed by the lecturer of the training. SwitchgearDesign permits to develop substation equipment simulating their performance in the tests before going to do a real test in laboratory. The program of this training course cover:

- Specification and testing of MV and LV switchboards, switchgear, transformers, circuit breakers, isolators, fuses, busways, etc.
- Details and understanding of opportunities to reduce the need of expensive testing according to IEC technical standards 62271-1 / 100 / 200 /307 (medium – high voltages) and IEC 61439 (low voltage)
- Laboratory tests methods (breaking, short circuit, internal arc, heating, electro dynamical forces, dielectric tests, mechanical tests and others)
- Calculation methods of electrical and mechanical effects and how to improve the design.
- Magnetic and electric fields mapping in substations to solve EMC problems
- How to use the software SwitchgearDesign to simulate and design your equipment for temperature rise, short time and crest current (electrodynamic forces), internal arc tests and electromagnetic fields

The lecturer of the training, Sergio Feitoza Costa, developed SwitchgearDesign 307 based in his experience in the design, operation and management of big size testing laboratories, especially high power and high voltage ones. He is for a long time member of IEC and Cigré working groups. He was Chairman of IEC Technical Committee 32 (Fuses). He is member of the working group WG 31 of IEC which is preparing the new IEC 62271-307 and also of the CIGRE WG which published in 2014 the CIGRE brochure "Tools for the simulation of internal arc effects in MV and HV switchgear “. He is also member of the Cigré working group WG A3.36 International - Application and Benchmark of Multi Physic Simulations and Engineering Tools for Temperature Rise Calculation.

- Links for free download: http://www.cognitor.com.br/en/site/index.php?sec=5

- CV: http://www.cognitor.com.br/en/site/index.php?sec=1

The software permit to reduce considerably the expenses with testing in labs. It is possible to simulate temperature rise tests, short time current tests (electro dynamical forces) and internal arc tests. The mapping of electric and magnetic fields may help in the solution of EMC (Electromagnetic Compatibility) problems. It is not an academic tool and have focus in solving problems of the daily life of an electrical equipment designer. Considering this, no explanation about calculation methods, CFD, finite volumes, etc are presented here. Nevertheless, some details and explanations may be found in the reference articles listed in the annexes.

Suggestions and proposals for new case studies for validation are 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 of a tested equipment is what is done in the document entitled “Guidelines for the use of simulations and calculations to replace some tests specified in international standards “(Annex F) or in the following link:
http://www.cognitor.com.br/GUIDE_Simulations_v0_October2010.pdf .

This report includes the following information:

- Standard / guideline for applying simulations to replace some laboratory tests (Annex F)
- User requirements (inputs and outputs for the calculations) (Annex G).

- The short manual is just the book which can be downloaded free in the following link. Section 7 is the main part related to the software and possibly the screens showed there are not updated 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 standard (Section 3).and acceptance criteria of simulations (Section 4).
- Information about the software design, implementation, programming language, operating technician support, installation and removal (Sections 4 to 6)

All methods and topics covered in this report were derived from efforts of Cognitor already registered and published in national and international references.

2. VALIDATION METHOD AND COMPARISON BETWEEN SIMULATION AND TEST RESULTS OR IEC STANDARDS. (TEMPERATURE RISE TESTS)

To compare test and simulation results we used laboratory test reports. In Table 2, there are test cases and references to the test reports used for comparisons, to the figures with input data used in the simulation and to the tables comparing test and simulation results.

Table 2 – Test Cases used for validation

	Test	Type of equipment (software screen) Case in the software database	Test report	Comments	FIGURES with inputs and simulation results	TABLE with comparison tests x simulation
1	Temperature rise AIS	LVSW-1 LVSW1_01_M_R67752	Test report 67752 (Annex D)	Circuit breaker 25 µΩ 768 w	Figure 1	Table 3
2	Temperature rise AIS	MVSW_1 MVSW1_02_M_R65111	Test report 65111 (Annex D)	Circuit breaker 54 µΩ	Figure 2	Table 4
3	Temperature rise AIS	Duct_1 Duct_03_3x150x10_R67 131	Test report 67131 (Annex D)	Connection joint 7 µΩ	Figure 3	Table 5
4	Temperature rise AIS or GIS	GIS_1ph GIS1ph_MissingReport_ 1ph AIR and SF6	No test report available	Connection joint 7 µΩ	Figure 4	Table 6
5	Temperature rise AIS or GIS	GIS_3ph GIS3ph_MissingReport_ 3ph AIR and SF6	No test report available	Connection joint 7 µΩ	Figure 5	Table 7
6	Temperature rise GIS	GIS_3ph GIS3ph_PaperSF62009 SF6	Article Note 1	No Connection joint	Figure 6	Table 8
7 To 9					Future use (Fig7 to 9))	Future use (Table 9-11)

	Test	Type of equipment (software screen) Case in the software database	Test report	Comments	FIGURES with inputs and simulation results	TABLE with comparison tests x simulation
10	Magnetic field inside a room 14m x 15 m x 10 m (h) due to a busbar 25000A	Duct1 Duct_04_ISI_ET_validate	Calculation using theoretical equation		Figure 10	Table 12
11	Magnetic field LV switchgear	LVSW-1 LVSW1_01_M_R67752			Figure 11	Table 13
12	Magnetic field GIS – 3ph	GIS_3ph GIS3ph_MissingReport_ 3ph	Enclosure Aluminum or enclosure common steel		Figure12	Table 14
13	Magnetic field Substation ISI	subSTISI subST_01_ISI			Figure13	Table 15
14	Electric Field Substation ISI	subSTISI subST_01_ISI			Figure 14	Table 16
15	Electric Field Substation ISI	subST subST_01_OneHalfCB			Figure 15	Table 17
16	Electric Field MV switchgear	MVSW_1 MVSW1_02_M_R65111			Figure 16	Table 18
17	Electric Field GIS – 3ph	GIS_3ph Duct_R67131_3ph			Figure 17	Table 19

Note 1: Article: Calculation of Temperature Rise in Gas Insulated Busbar by Coupled Magneto-Thermal-Fluid Analysis – Authors Hong-Kyu Kim†, Yeon-Ho Oh* and Se-Hee Lee**
Published in Journal of Electrical Engineering & Technology Vol. 4, No. 4, pp. 510~514, 2009

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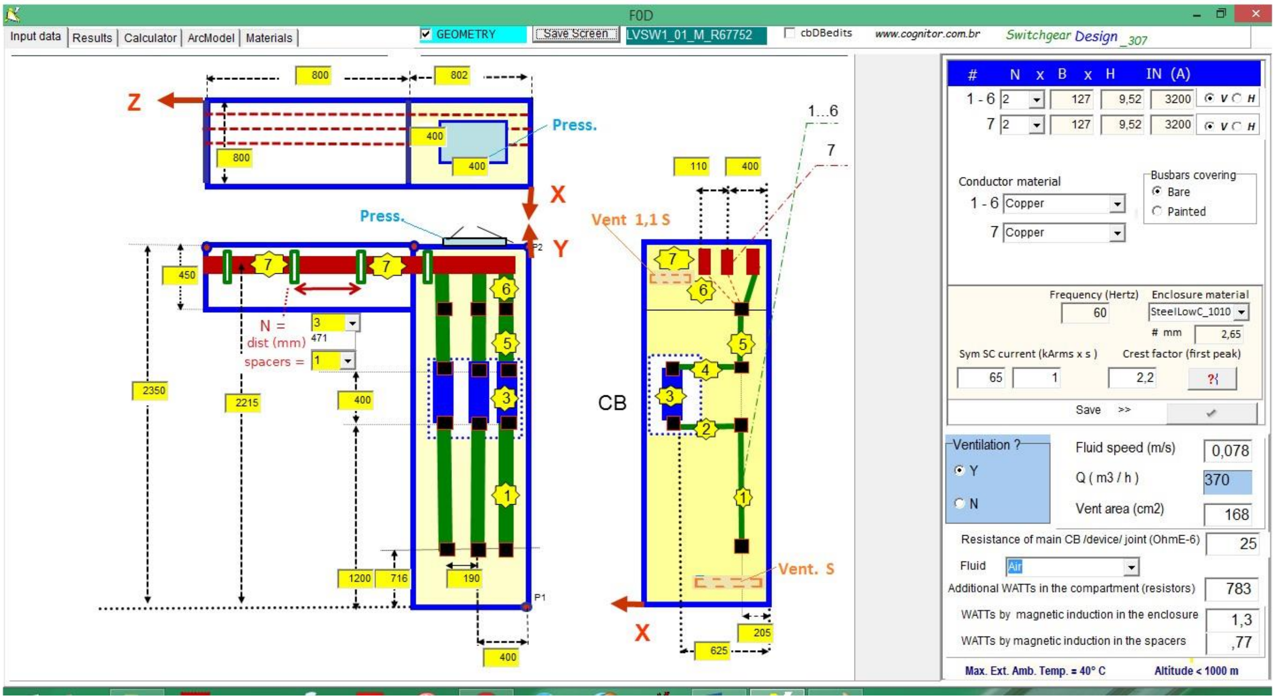
Figure 1 – LVSW1 – TEMPERATURE RISE TEST
INPUT DATA AND RESULTS - LVSW1_01_M_R67752



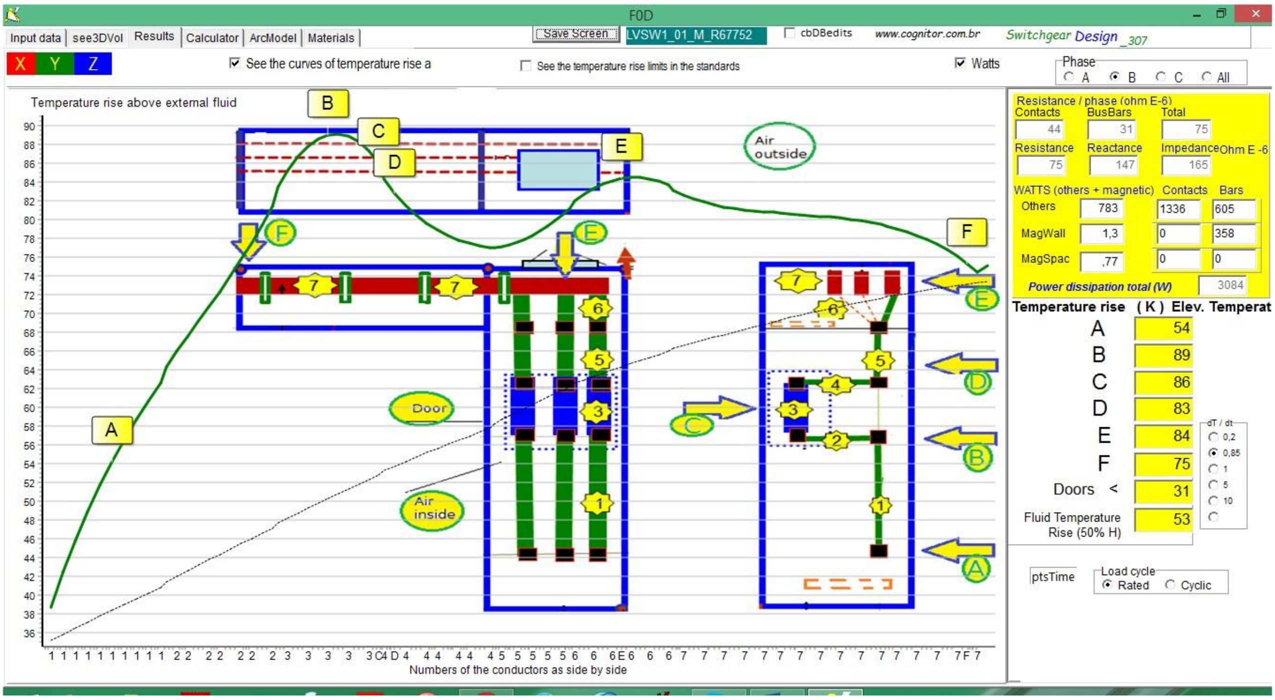


Table 3 – LVSW1 – Temperature rise test LVSW1_01_M_R67752
Bare bus bar. With ventilation openings – 180 m3/h air flux corresponding to an average air speed of 0,078 m/s = 180 / (0,8x0,8) , effective area for the air input 168 cm2 Additional thermal load 783 W (to be added to bus bar resistances and connections 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	54	< 5 %
B – C – D – connection between bars and circuit breaker (**)	78 to 89	83 to 89	< 5 %
E – Connection between the horizontal and vertical bars	76	84	< 10 %
F – Short circuit point	46 (***)	75	Thermocouple?
Door	8 (*)	<31	< depend on height
Internal air	32 (*)	36 to 73	(*)

(*) The measuring position during the test is not indicated in the test report (no pictures) and the value can change very much with position. In the simulation, the bottom has 36K and ceiling is 73K. For the average height is 53K. See the black curve graph showing temperatures along the height.
(**) Critical point in testing
(***) possibly the thermocouple was not properly secured. See temperature point E - same bar

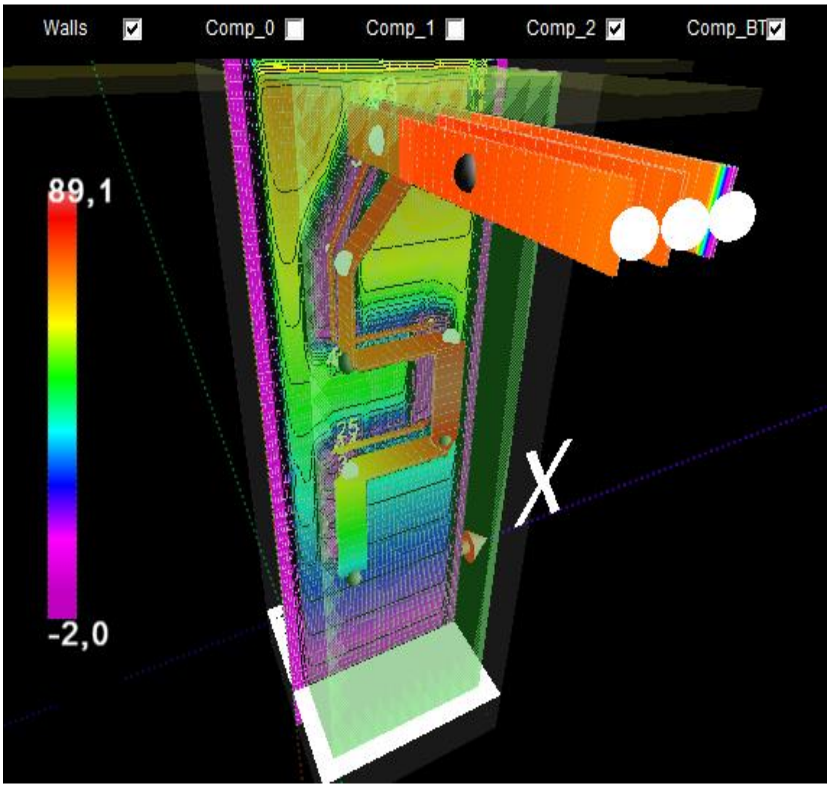
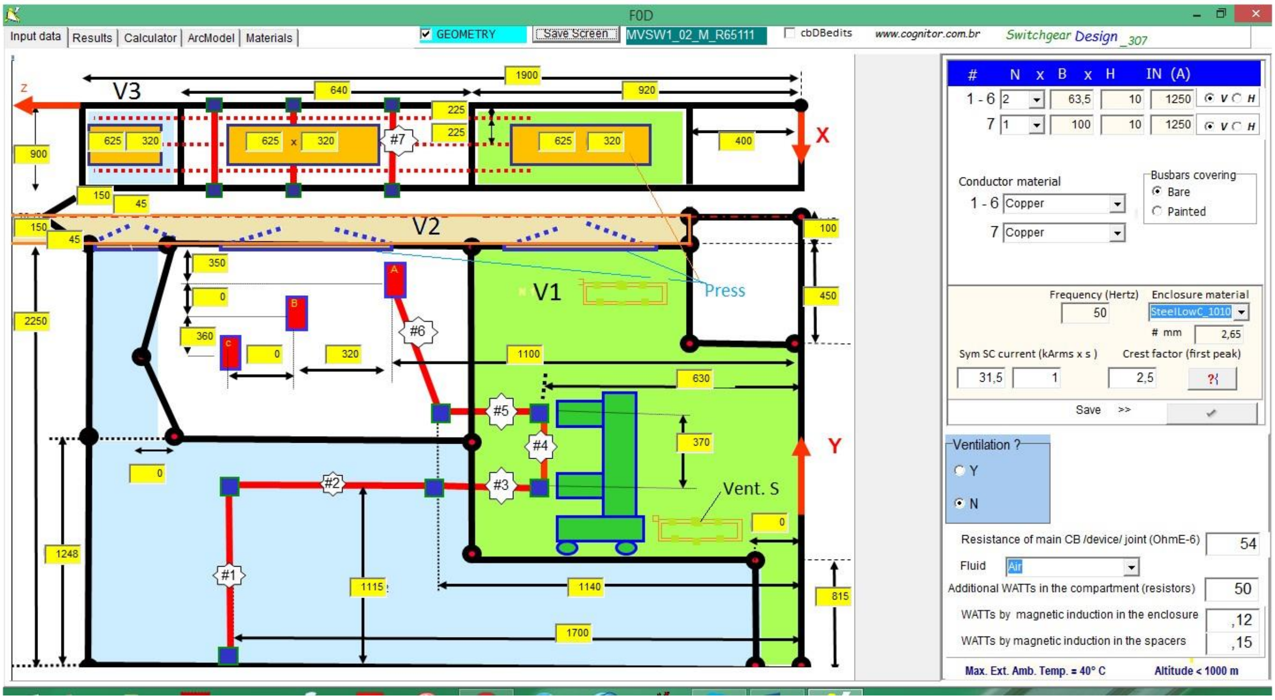


Figure 2	– MVSW1 –	Temperature rise test
INPUT DATA AND RESULTS	MVSW1_02_M_R65111	



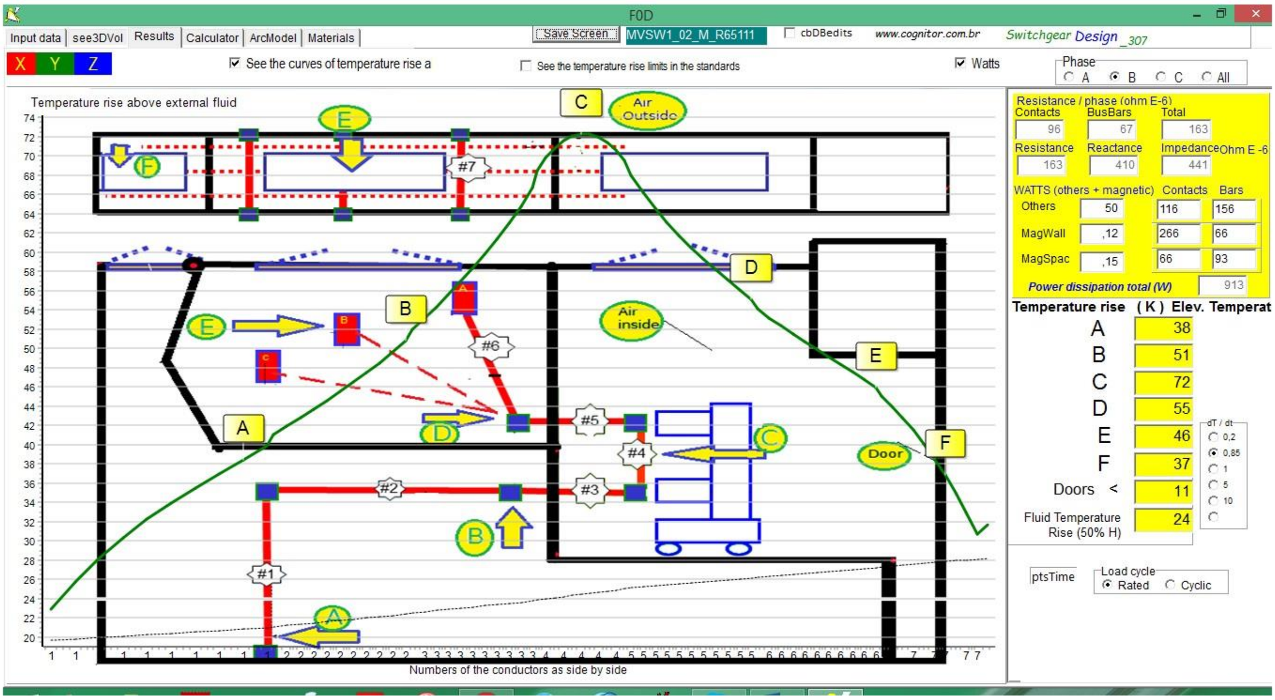


Table 4 – MVSW1 – Temperature rise test MVSW1_02_M_R65111
Bare bus bar Without ventilation openings
Circuit breaker resistance as seen from the terminals – 54 μΩ per phase

Measuring point	Test temperature rise (K)	Simulation (K)	Difference
A - Terminals for the connection to external conductors	39	38	< 5 %
B – C – D – connection between bars and circuit breaker (**)	56 to 72	55 to 72	< 5 %
E – Connection between the horizontal and vertical bars	44	46	< 5 %
F – Short circuit point	34	37	< 9 %
Door	12 (*)	11	< 15 %
Internal air	Not measured	18 to 26	(***)

(*) The measurement position during the test is not indicated (no pictures) in the test report and the value can change very much with position.
(**) Critical point in testing
(***) in the simulation, the bottom has 18K and ceiling is 26 K. For the average height is about 22K.

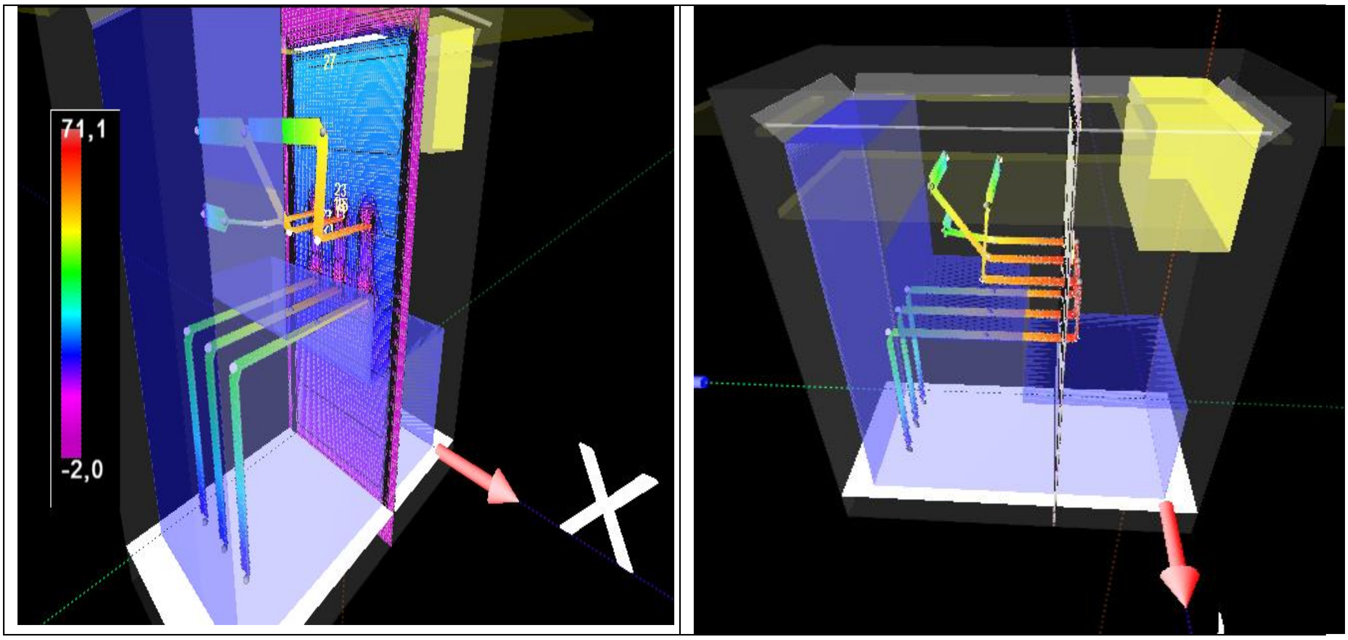
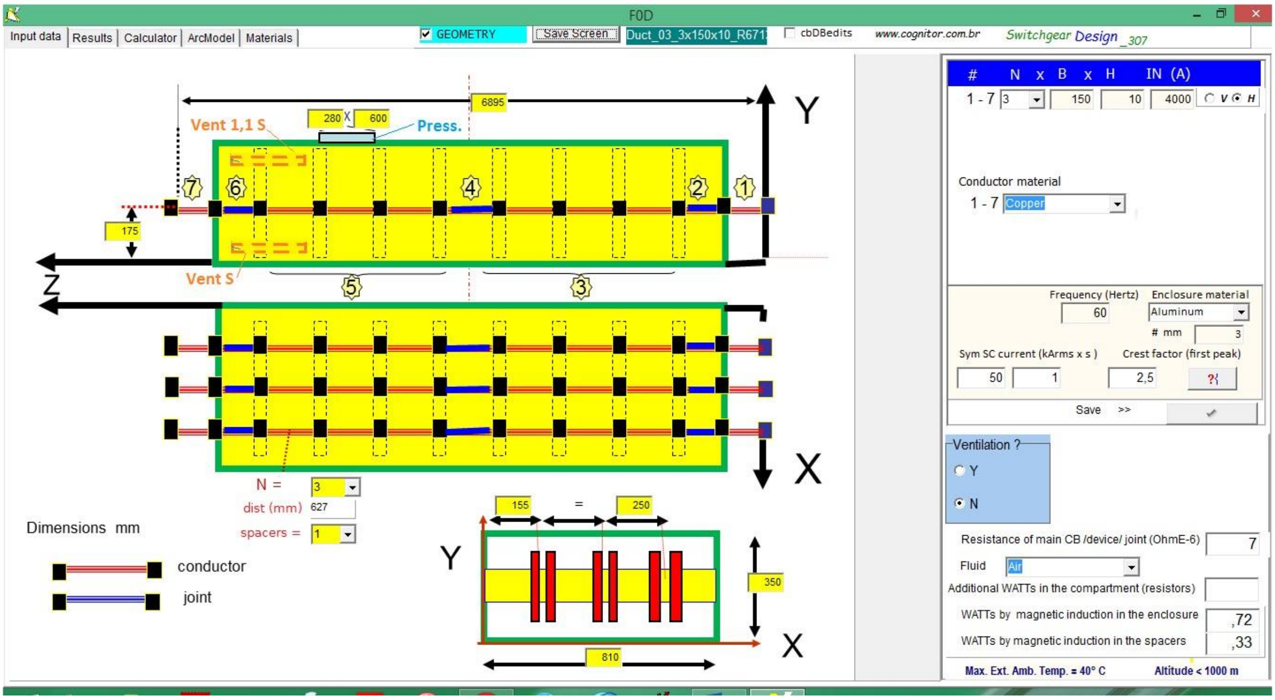


Figure 3 DUCT1 Temperature rise test	
INPUT DATA AND RESULTS	Duct_03_3x150x10_R67131



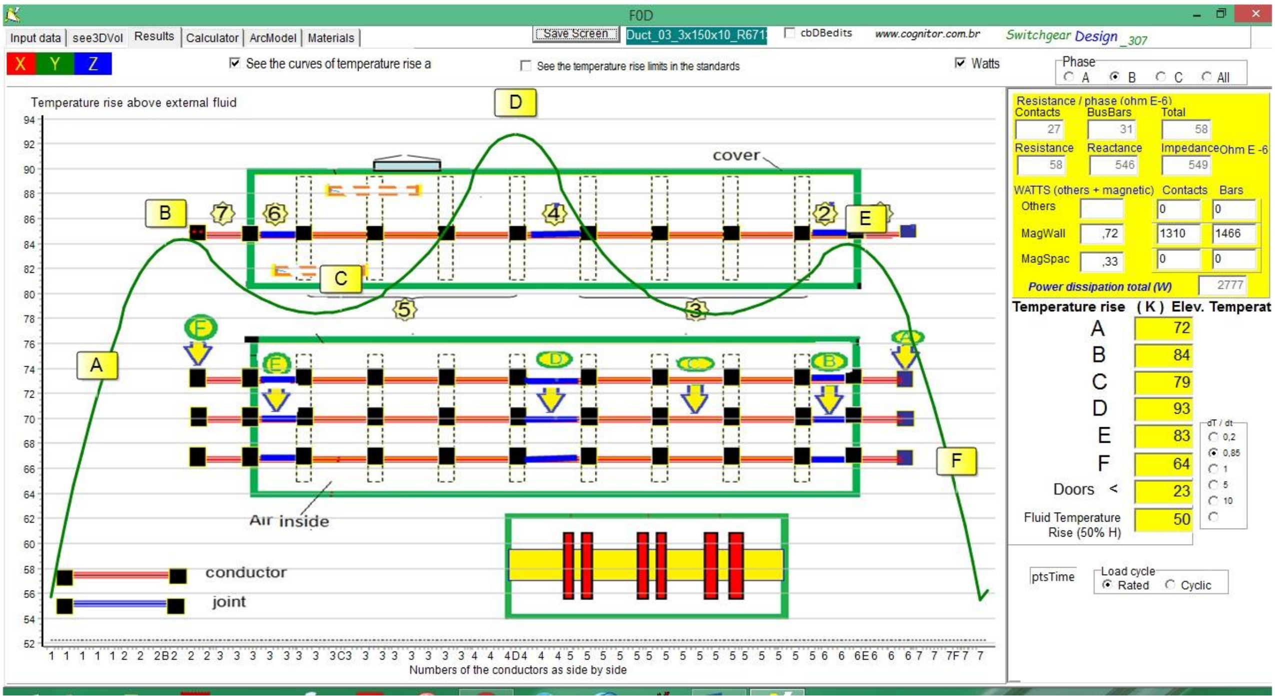
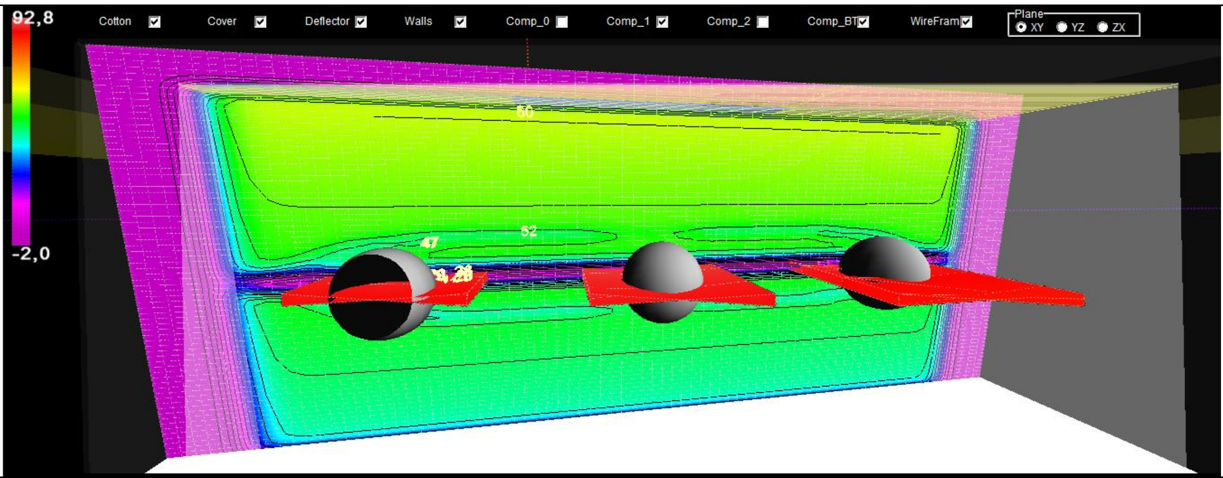


TABLE 5 DUCT1 TEMPERATURE RISE TEST Duct_03_3x150x10_R67131
Bare bus bar Without ventilation openings Connection / joint resistance 7 µΩ

Measuring point	Test temperature rise (K)	Simulation (K)	Difference
A - Terminals for the connection to external conductors	72,4	73	< 5 %
B – Conductor # 2	Not measured	84	-
C – Conductor #3	83,9	79	< 6 %
D – Conductor #4 (** connection)	84,5	93	< 10 %
E – Conductor # 6	Not measured	83	-
F – #7 – Short circuit point	66,6	64	< 5 %
Side of the enclosure	30 (*)	23	(*)
Internal air (50% H)	Not measured	50	-

(*) The measurement position during the test is not indicated (no pictures) in the test report and the value can change very much with position.
(**) Critical point in testing



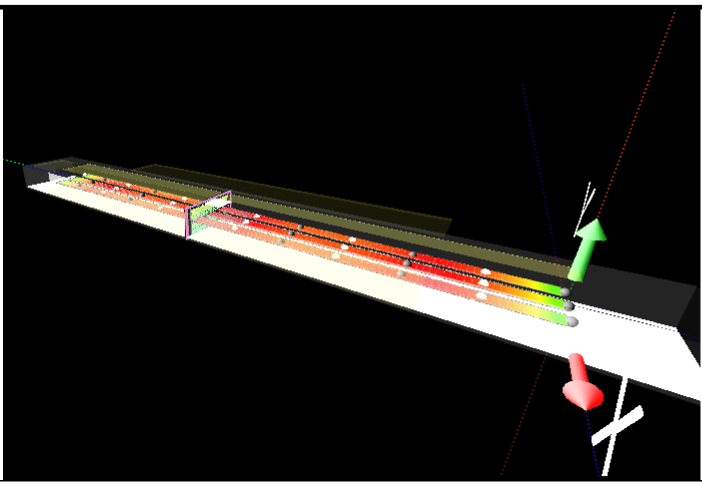
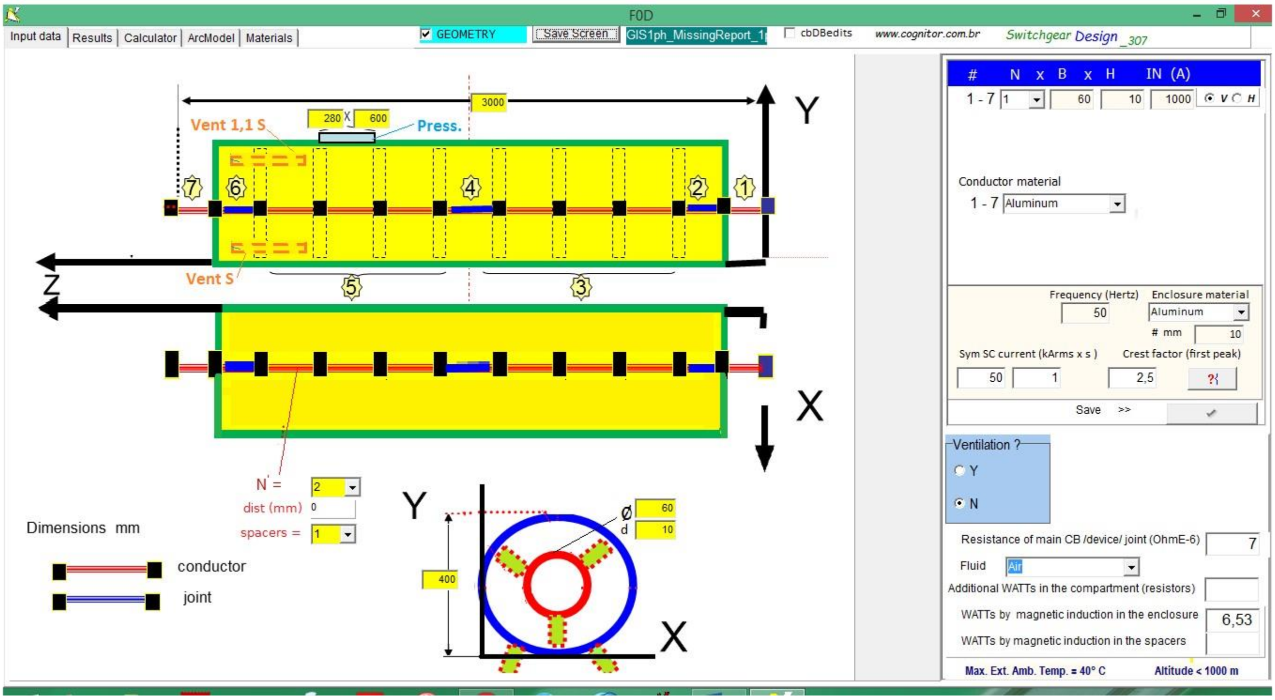


Figure 4 GIS_1PH Temperature rise test (Air or SF6)
INPUT DATA AND RESULTS GIS1ph_MissingReport_1ph



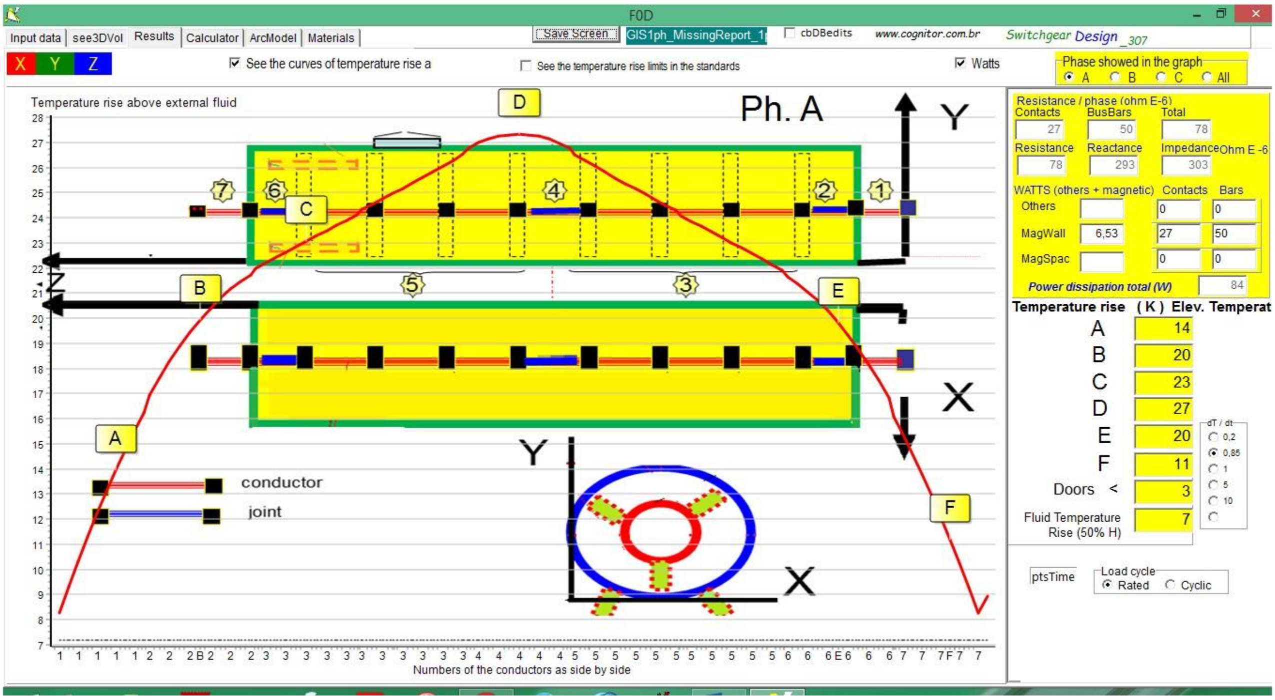
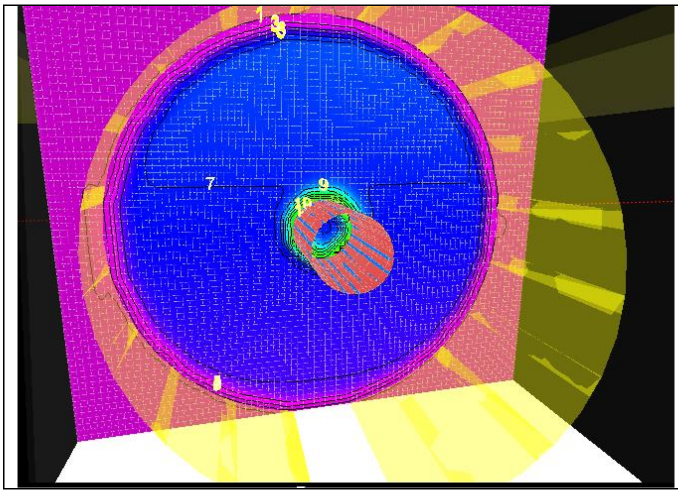


TABLE 6	GIS_1PH	Temperature rise test	GIS1ph_MissingReport_1ph
Bare bus bar	Without ventilation openings	Connection / joint resistance	7 µΩ

Measuring point	Test temperature rise (K)	Simulation AIR (K)	Simulation SF6 (K)
A - Terminals for the connection to external conductors	(*)	14	13
B – Conductor # 2	(*)	20	18
C – Conductor #3	(*)	23	20
D – Conductor #4 (** connection)	(*)	27	24
E – Conductor # 6	(*)	20	18
F – #7 – Short circuit point	(*)	11	11
Side of the enclosure	(*)	3	3 (***)
Internal air (50% H)	(*)	7	7 (***)

(*) No test report is available to compare with these results.
(**) Critical point in testing
(***) the same value of air was used. The correct values would depend on the pressure (considered equal in both cases)



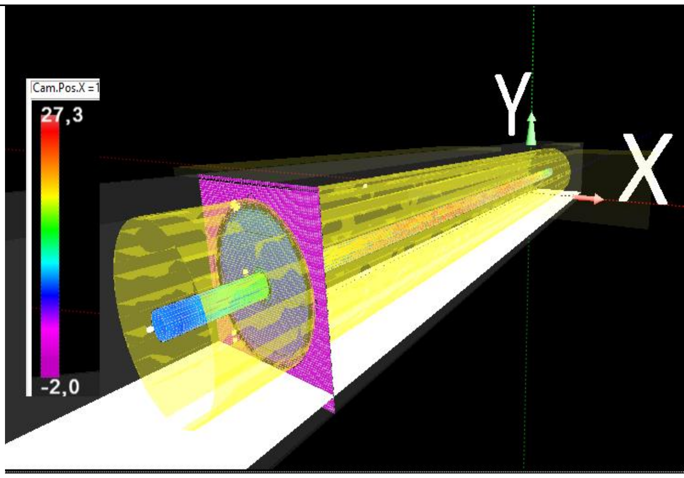
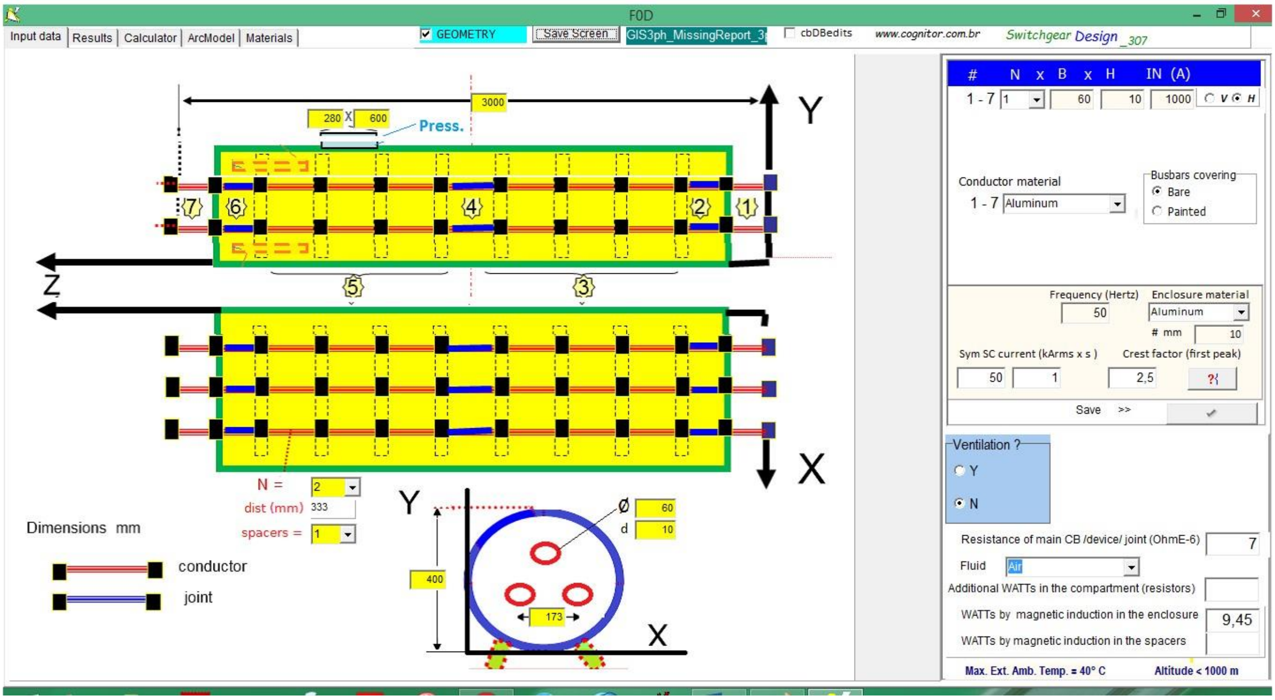


Figure 5 GIS_3PH	Temperature rise test
INPUT DATA AND RESULTS	GIS3ph_MissingReport_3ph



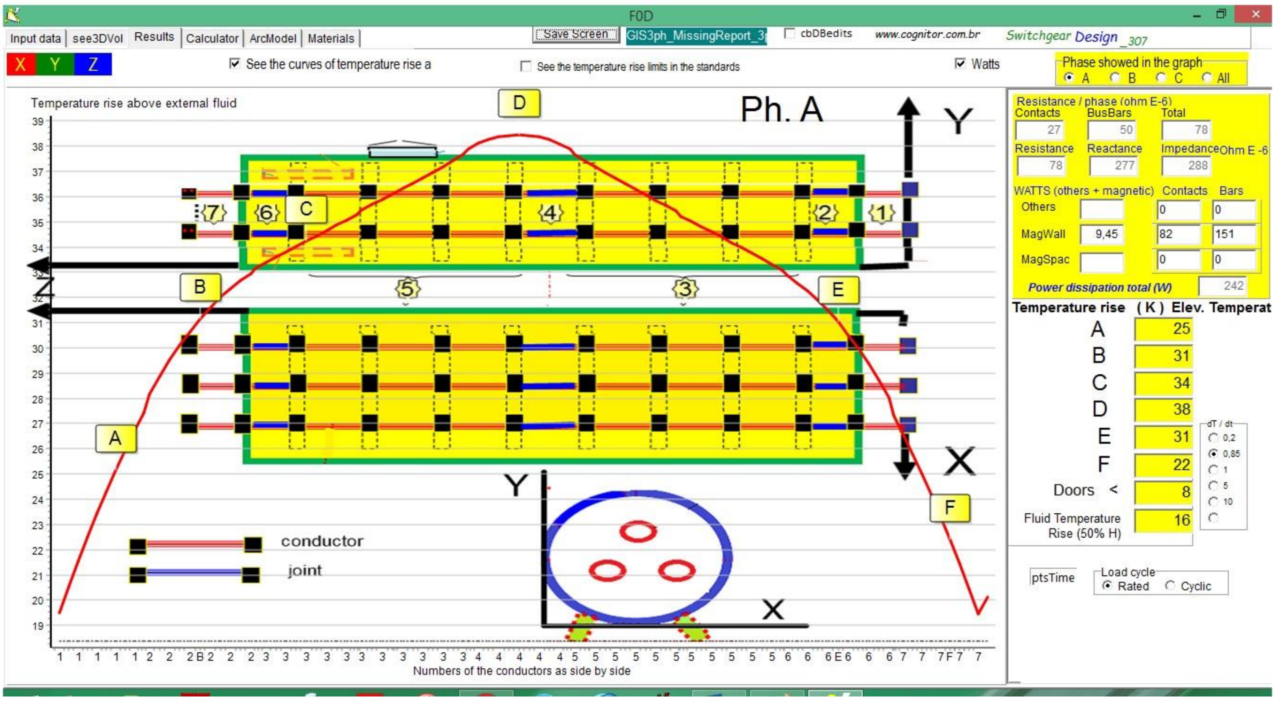
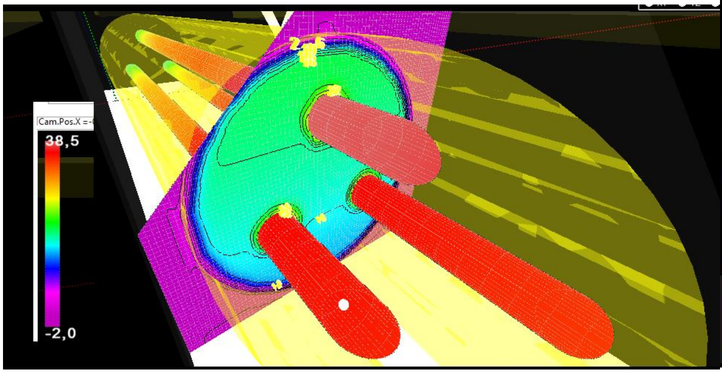


TABLE 7	GIS_3PH	Temperature rise test	GIS3ph_MissingReport_3ph
Bare bus bar	Without ventilation openings	Connection / joint resistance	7 μΩ

Measuring point	Test temperature rise (K)	Simulation AIR (K)	Simulation SF6 (K)
A - Terminals for the connection to external conductors		25	24
B – Conductor # 2		31	29
C – Conductor #3		34	31
D – Conductor #4 (** connection)		38	35
E – Conductor # 6		31	29
F – #7 – Short circuit point		22	22
Side of the enclosure		8	8 (***)
Internal air (50% H)		16	16 (***)

(*) No test report is available to compare with these results.
(**) Critical point in testing
(***) value to be corrected for SF6

Temperature rise



Magnetic field

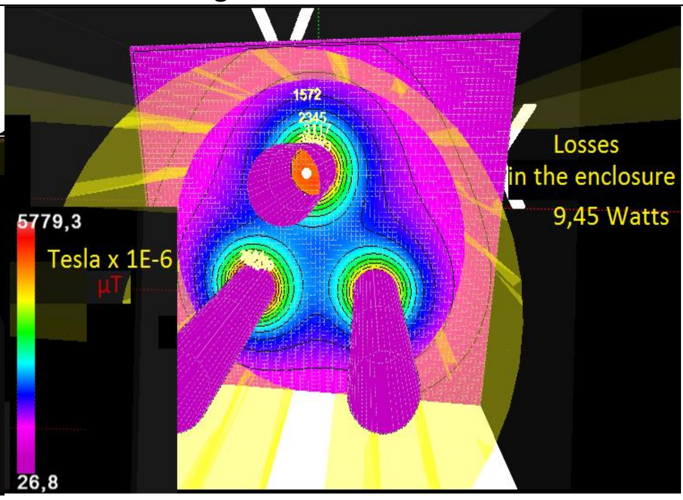
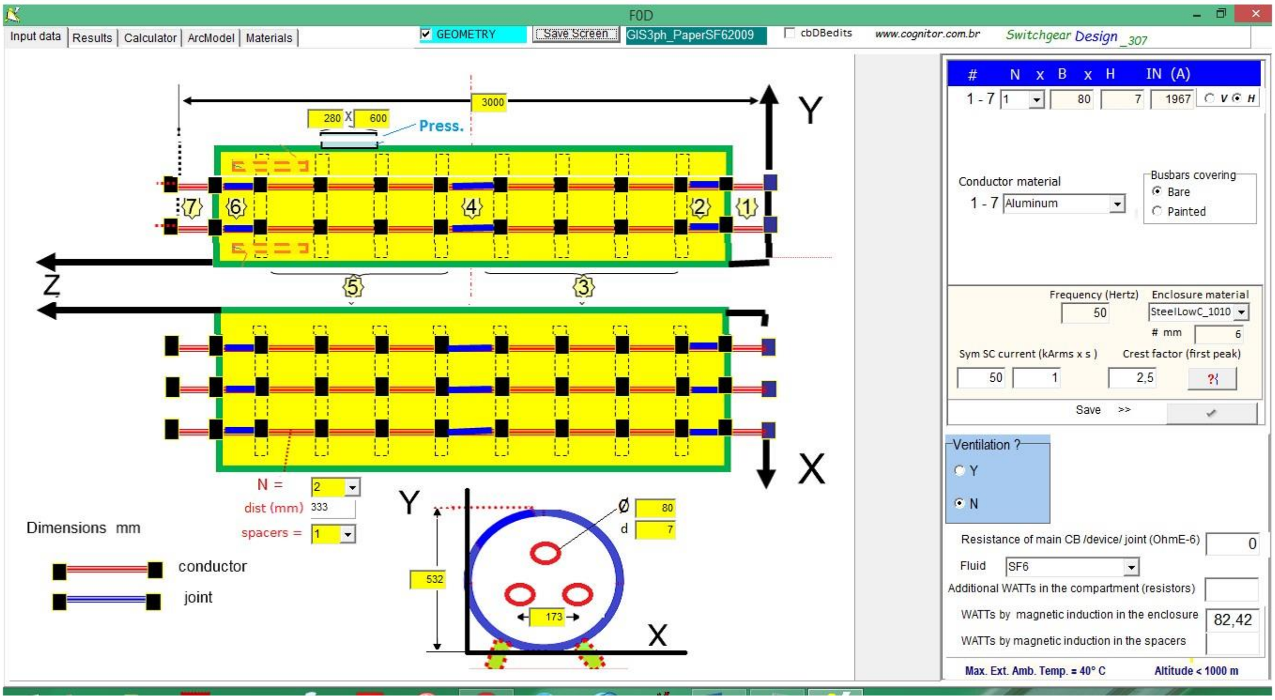


Figure 6 GIS_3PH Temperature rise test	
INPUT DATA AND RESULTS	GIS3ph_PaperSF62009



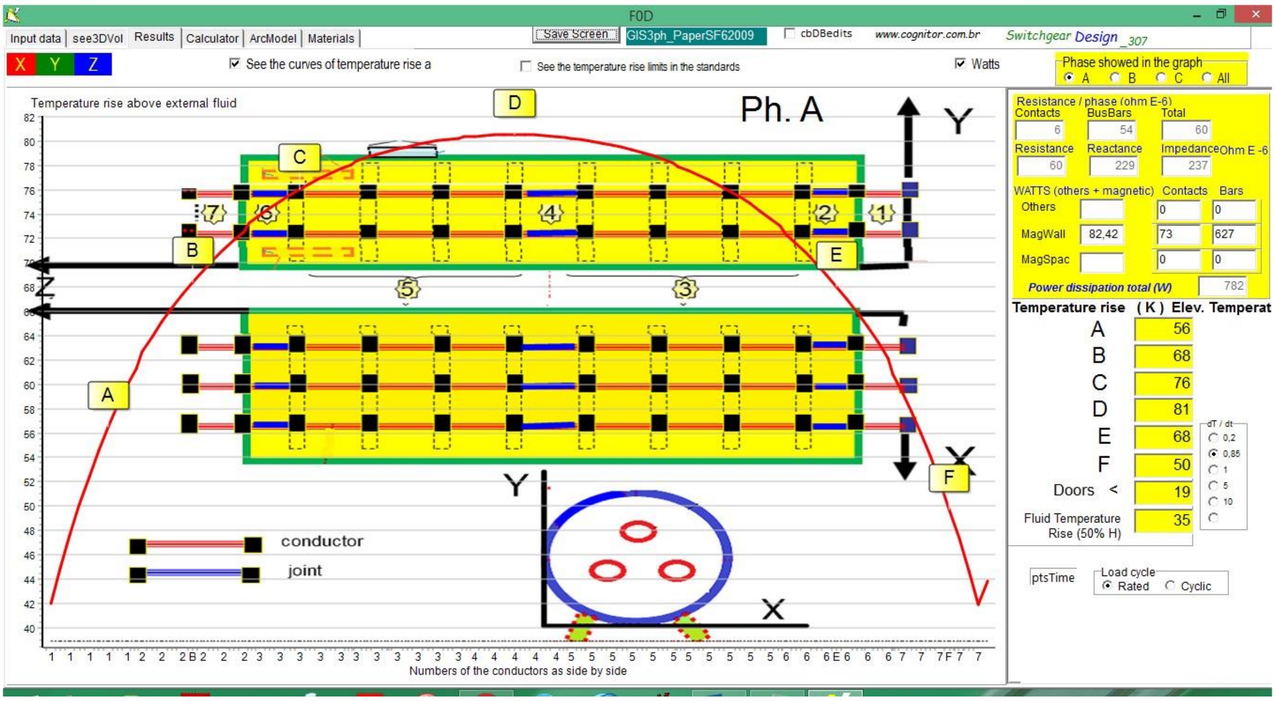


TABLE 8 GIS_3PH Temperature rise test GIS3ph_PaperSF62009
Bare bus bar Without ventilation openings Connection / joint resistance 0 µΩ

Measuring point	Test temperature rise (K)	Simulation SF6 (K)	Difference
A - Terminals connection to external conductors		56	
B – Conductor #		68	
C – Conductor #3		76	
D – Conductor #4 (** connection)	88 (*)	81	
E – Conductor # 6		68	
F – #7 – Short circuit point		50	
Side of the enclosure	47 to 52 (*)	19 (outside)	
Internal air (50% H)		35	

(*) Verifying with the author if this is temperature or temperature rise. It is not mentioned in the paper the temperature of the air outside

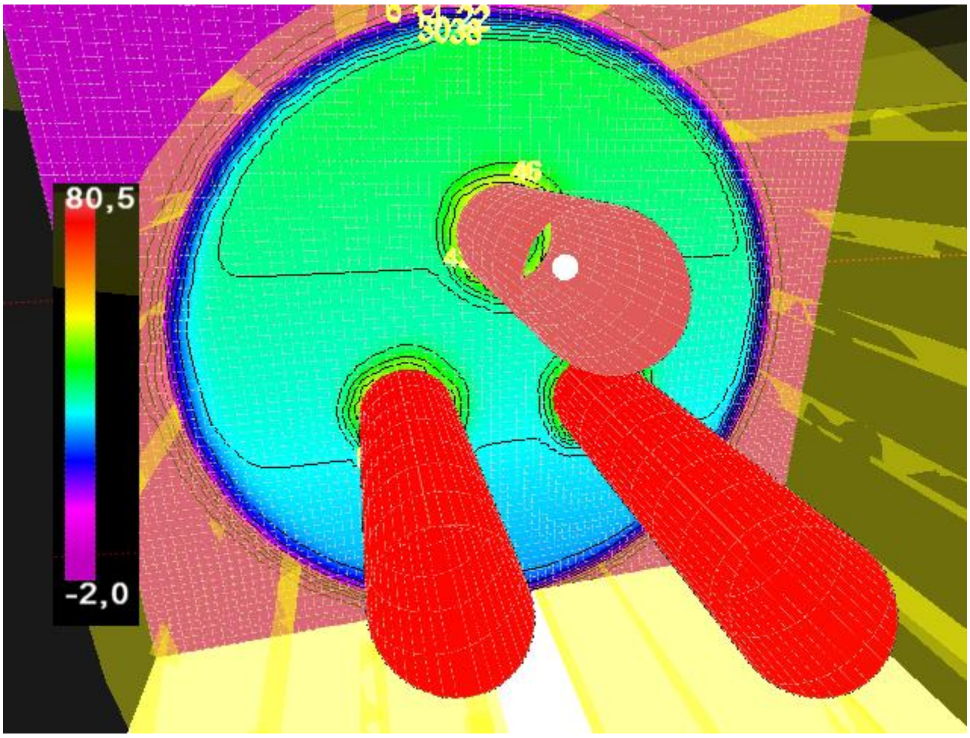
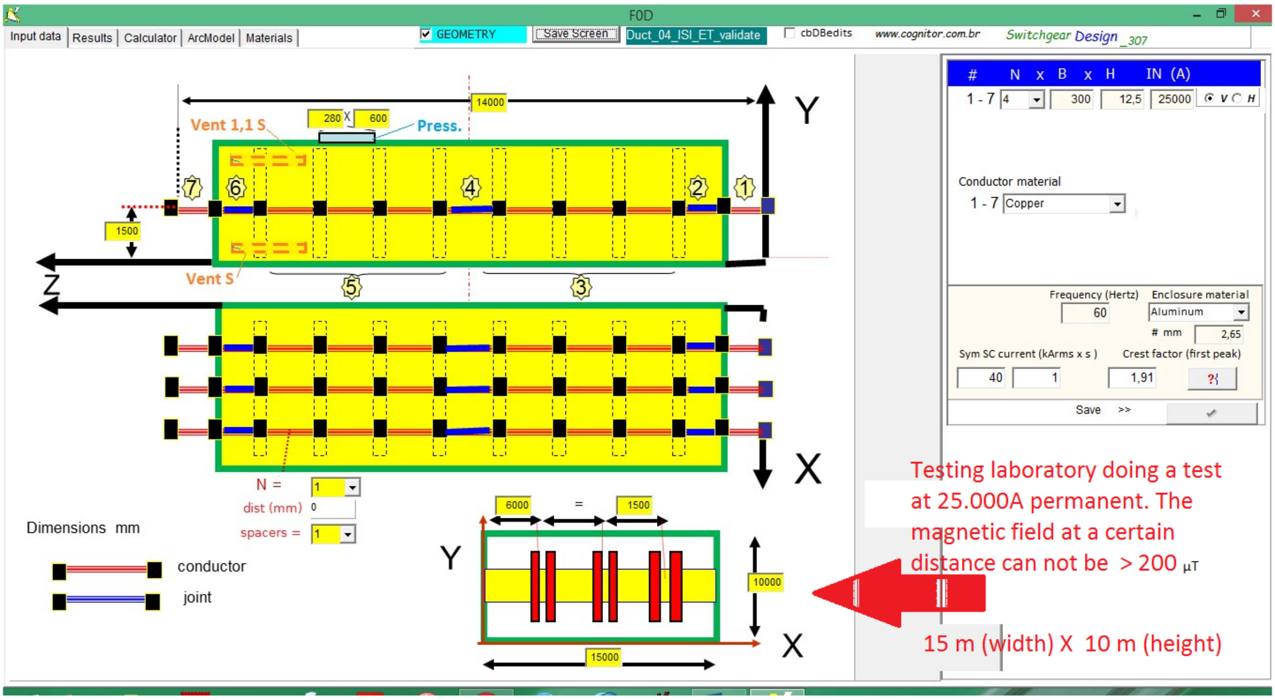
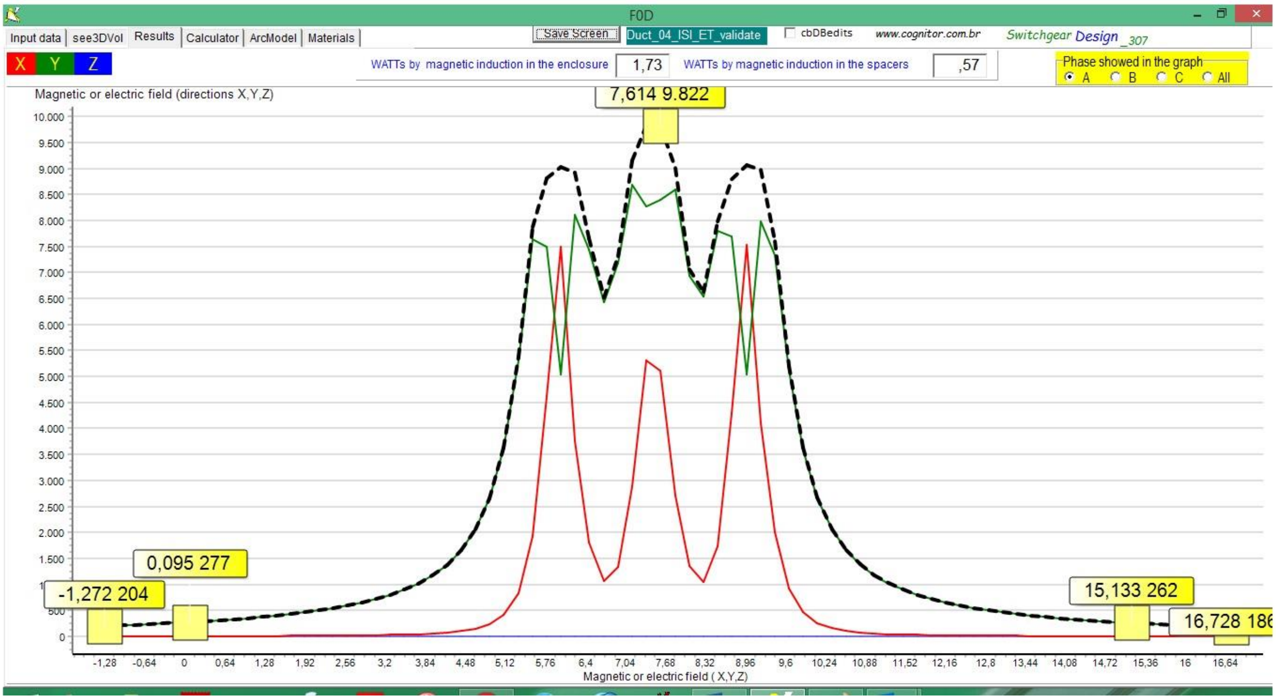


Figure 10	MAGNETIC FIELD MAPPING
INPUT DATA AND RESULTS	Duct_04_ISI_ET_validate

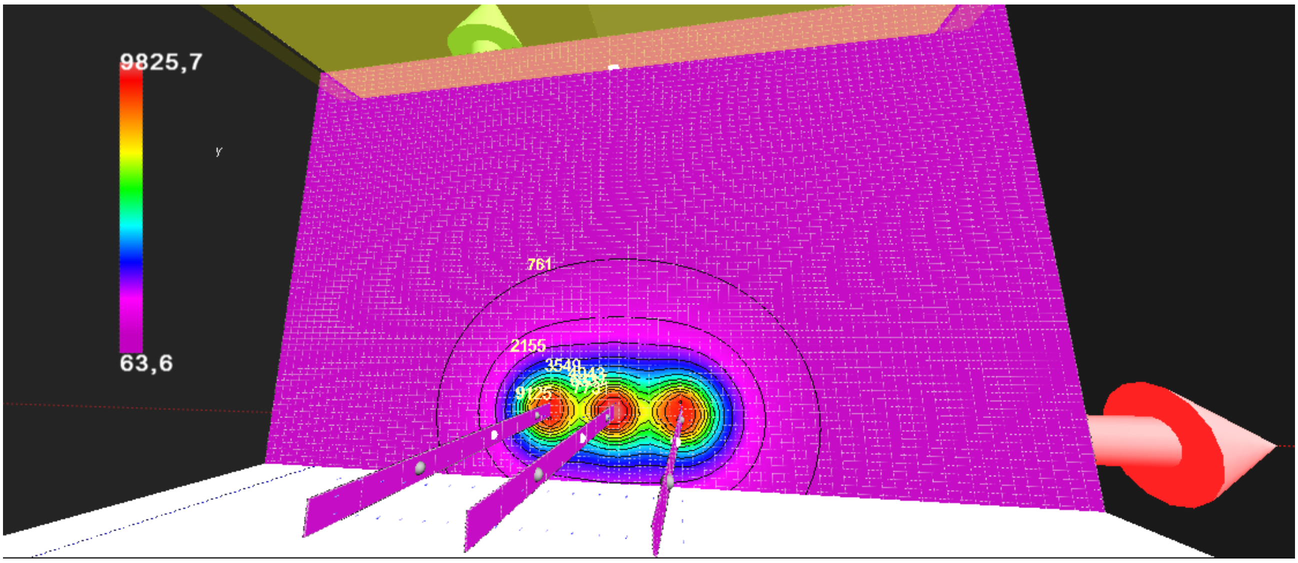
Values in µT (Tesla x 10^{-6})



Magnetic field in a central plane at 1,5 m height with 3-phase currents



Three phase currents



Current only in two phases (phase to phase)

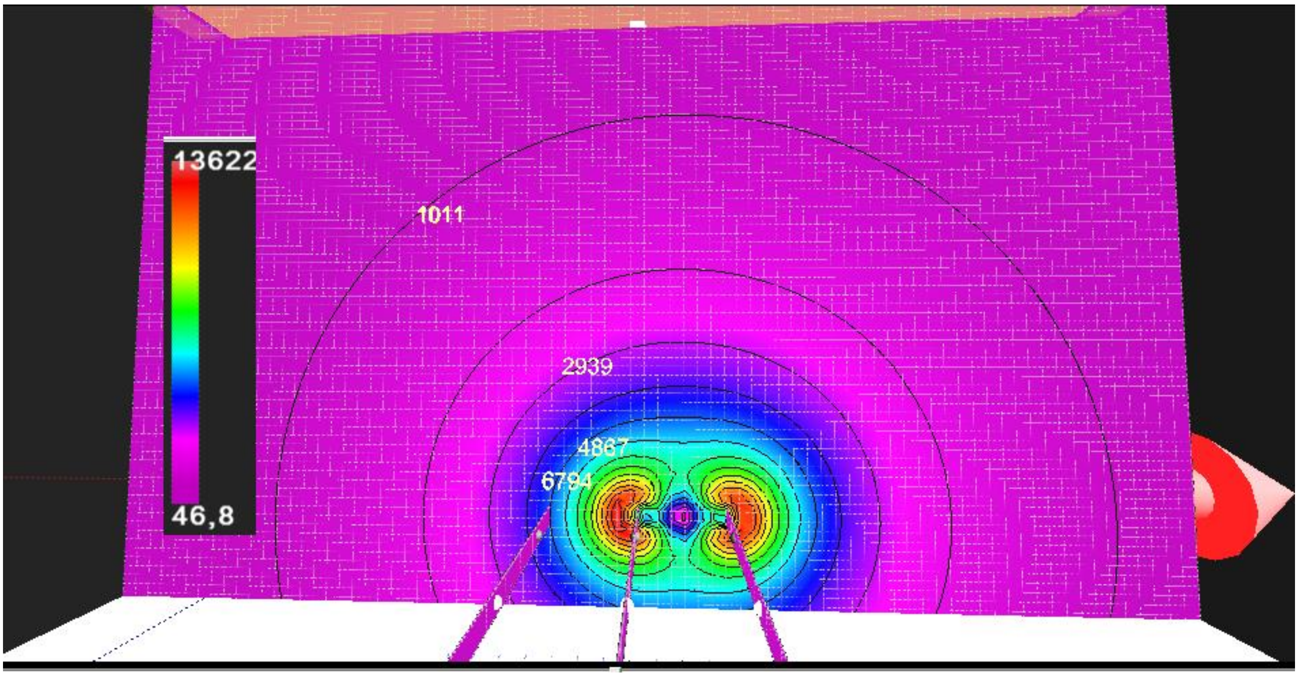
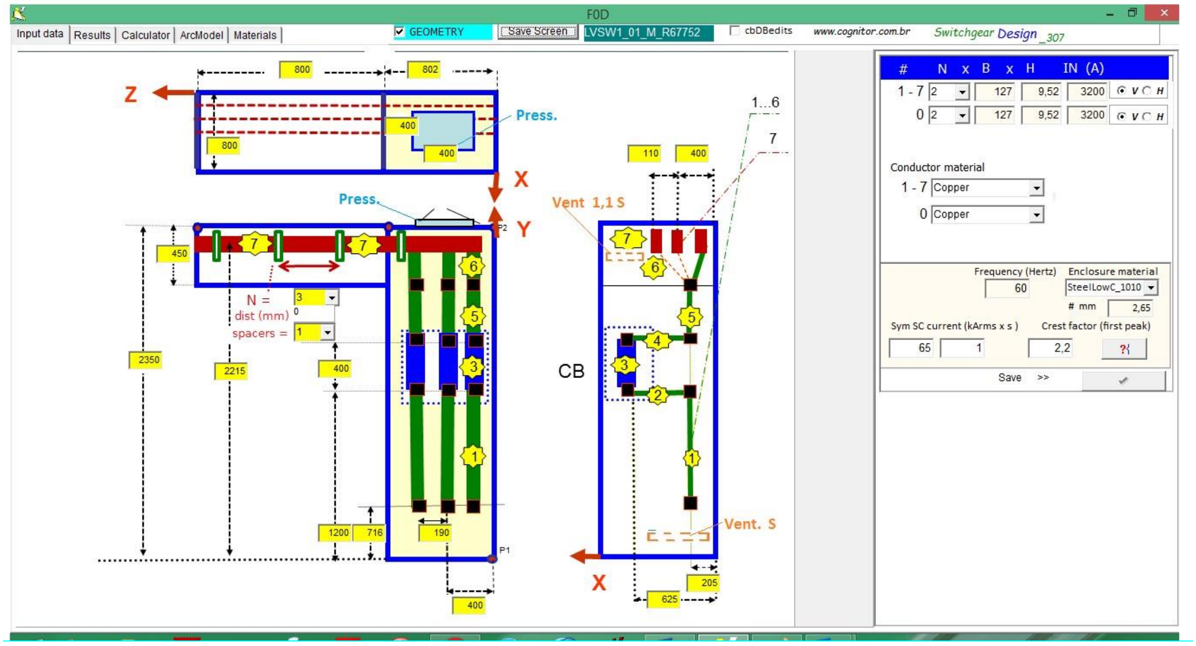
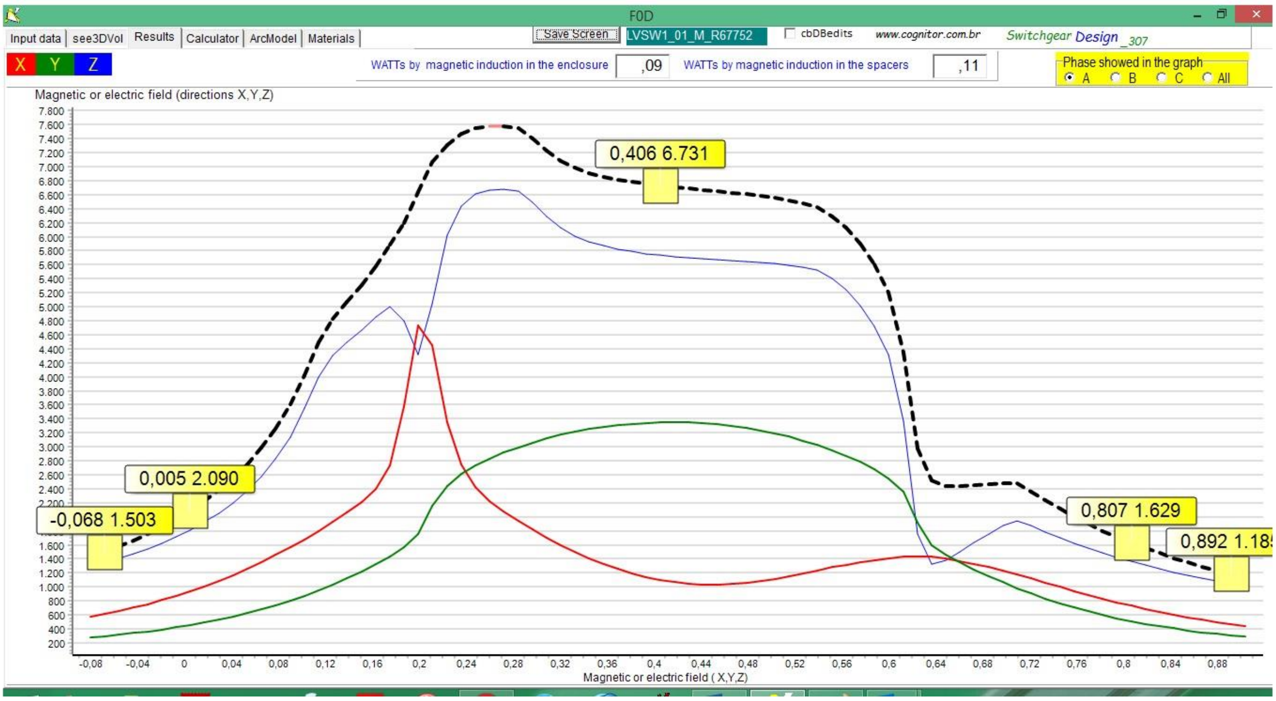


TABLE 12	MAGNETIC FIELD MAPPING	Duct_04_ISI_ET_validate
To complete after		

Figure 11	MAGNETIC FIELD MAPPING
INPUT DATA AND RESULTS	LVSW1_01_M_R67752

Magnetic field inside a low voltage switchgear
(Three phase currents 3200 A and with aluminum enclosure + non-magnetic supports)





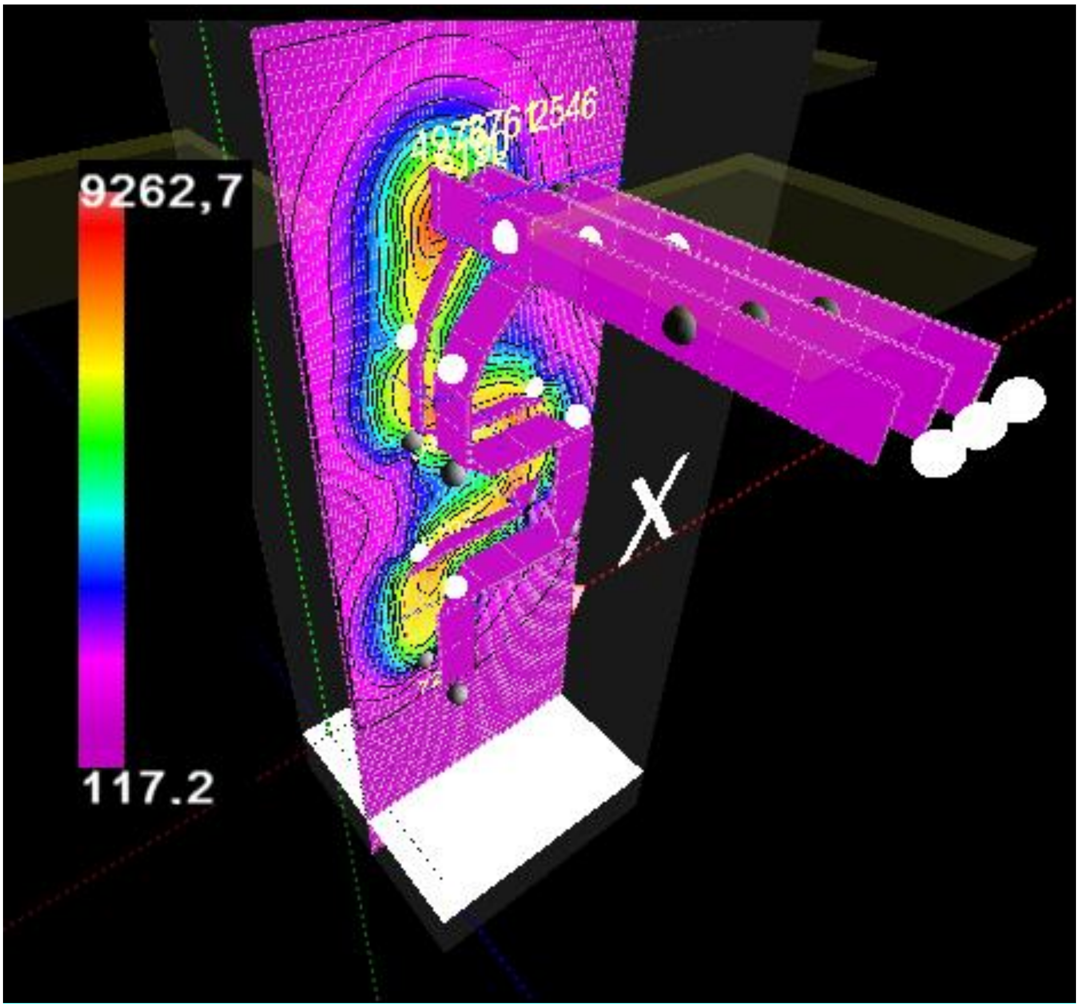
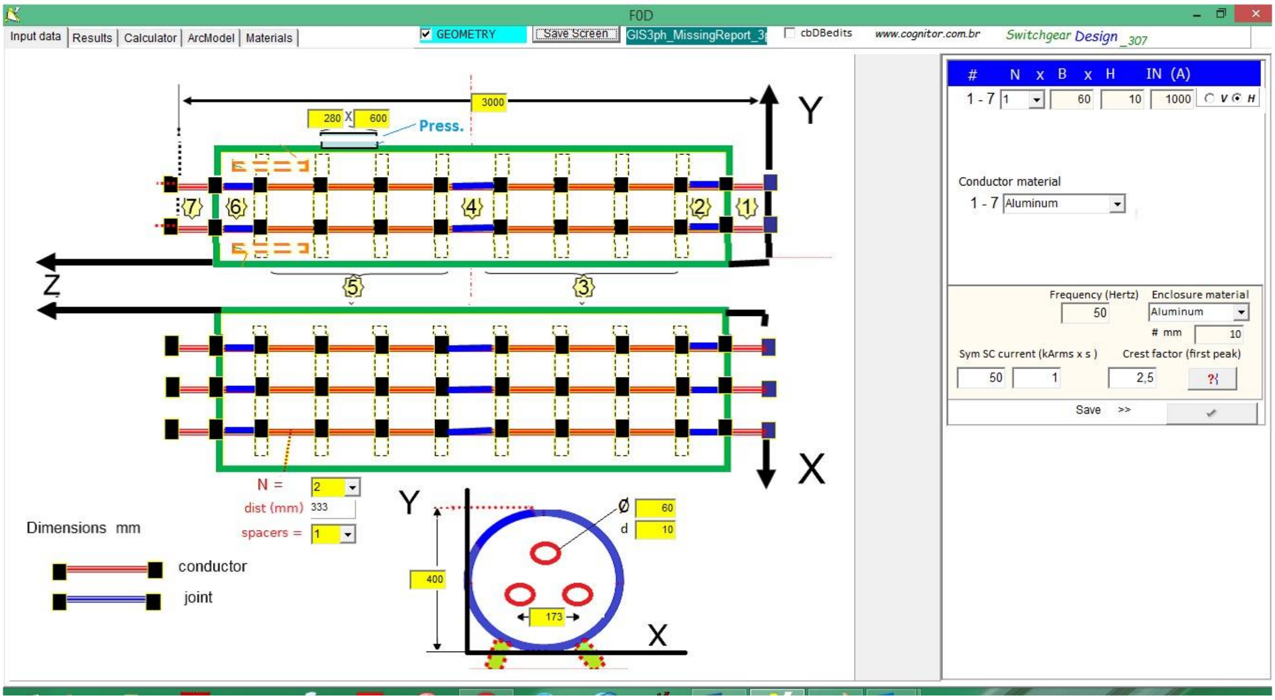
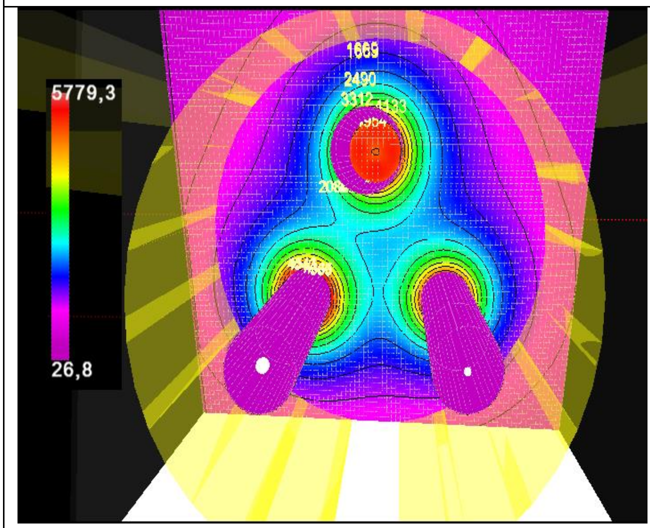
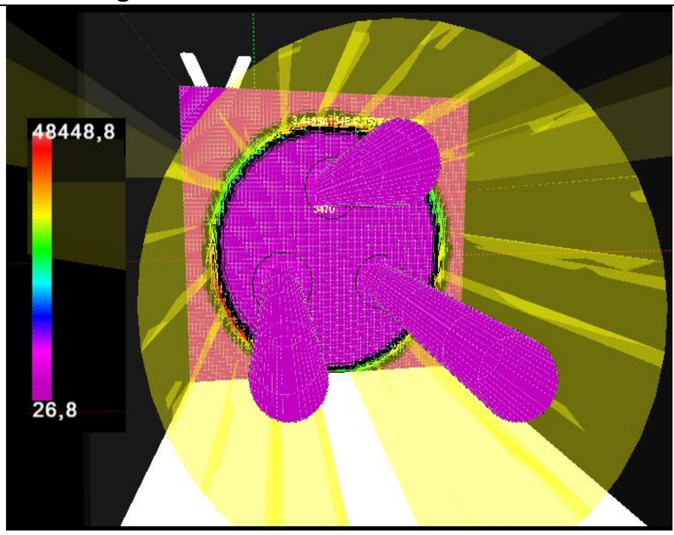


TABLE 13	MAGNETIC FIELD MAPPING	LVSW1_01_M_R67752
To complete after		

Figure 12	MAGNETIC FIELD MAPPING
INPUT DATA AND RESULTS	GIS3ph_MissingReport_3ph

With Aluminum enclosure or common steel enclosure



Aluminum enclosure Low fields and losses in the enclosure	Steel lowC enclosure High fields and losses in the enclosure
	

Depending of the material of the enclosure or the material of spacer or supports of busbar, for example in cubicles, a considerable power loss is produced by magnetic induction

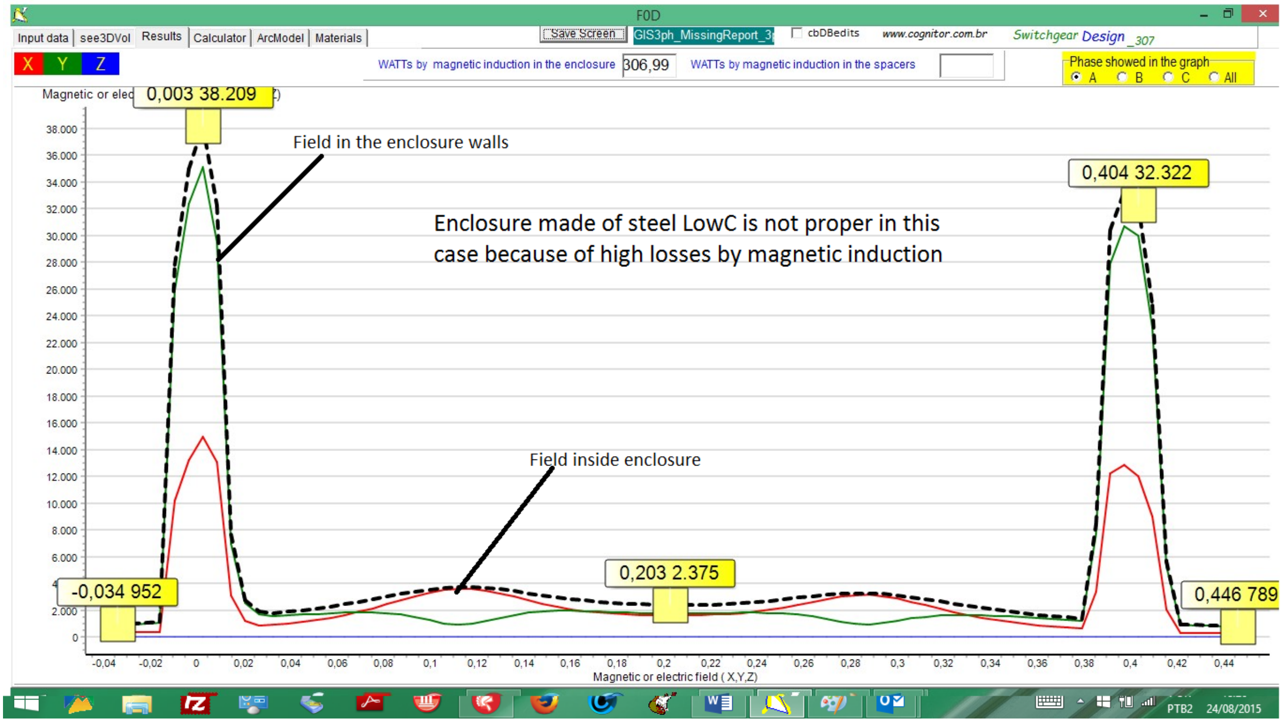
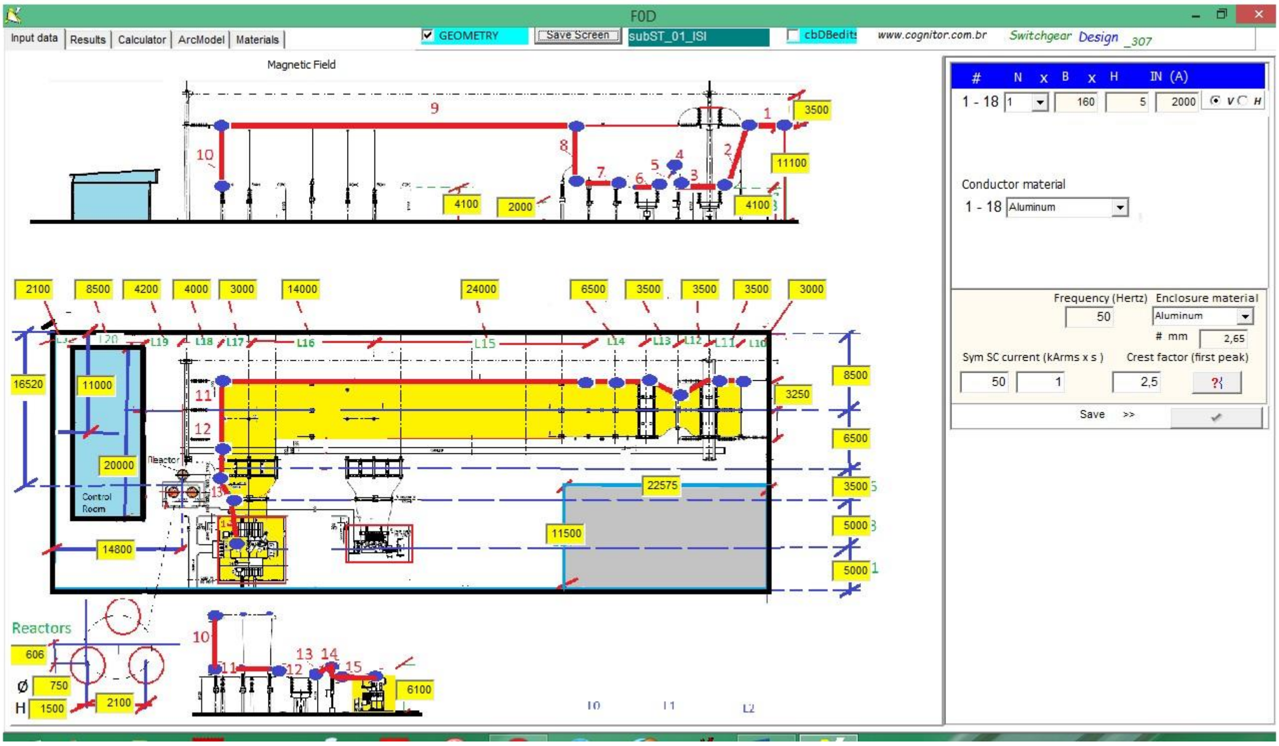


TABLE 14	MAGNETIC FIELD MAPPING	GIS3ph_MissingReport_3ph

Figure 13 MAGNETIC FIELD MAPPING
INPUT DATA AND RESULTS subST_01_ISI



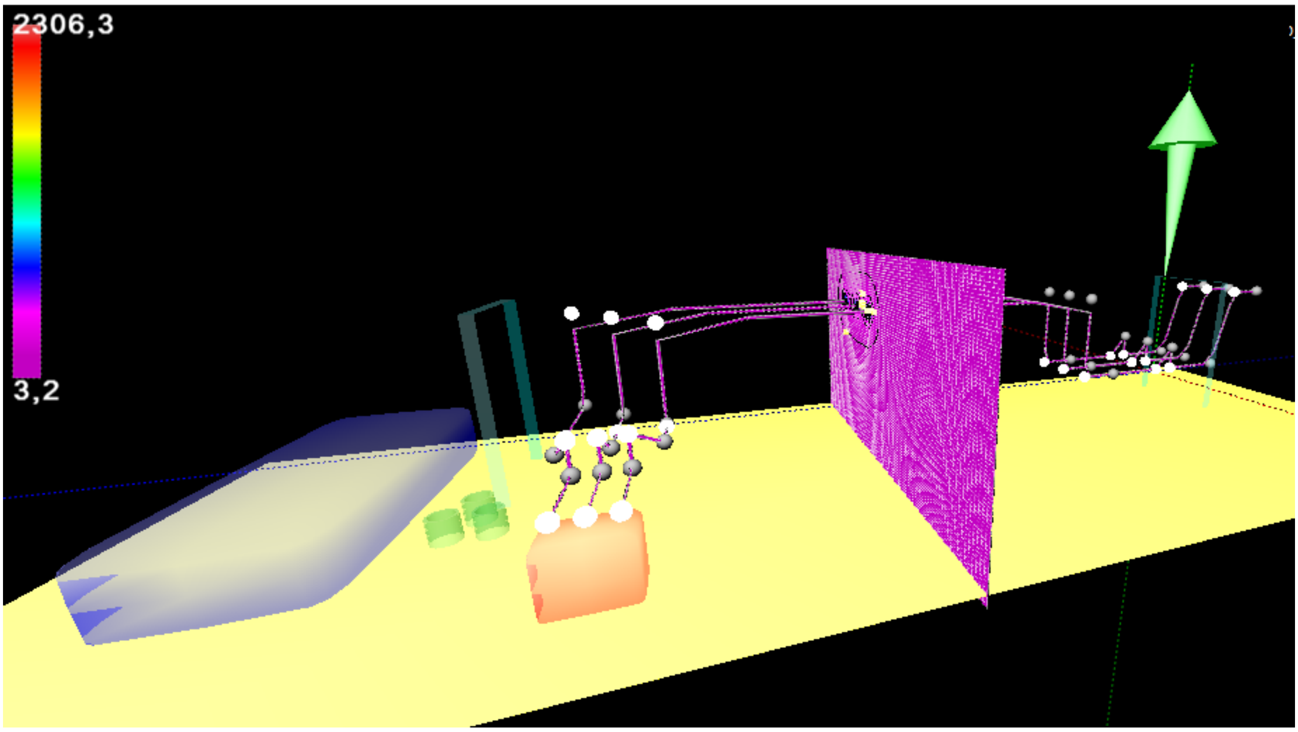
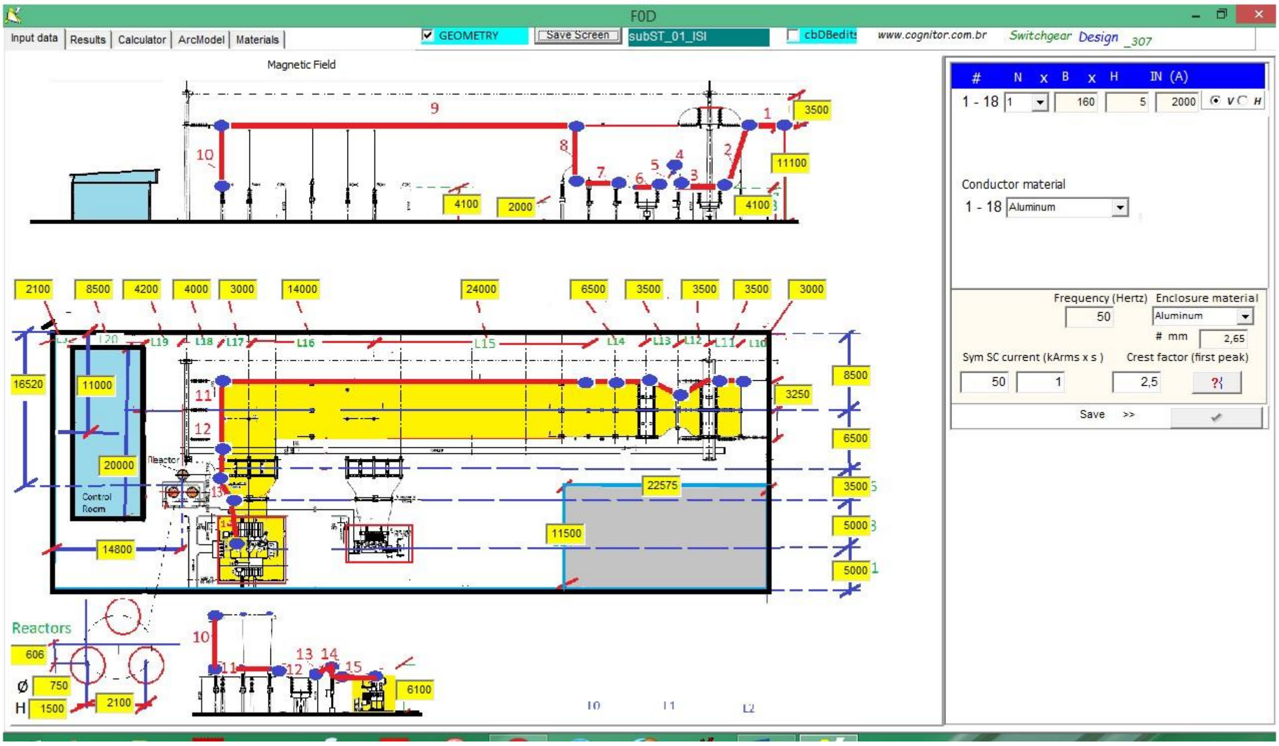


TABLE 15 MAGNETIC FIELD MAPPING subST_01_ISI

Figure 14	ELECTRIC FIELD MAPPING
INPUT DATA AND RESULTS	subST_01_ISI



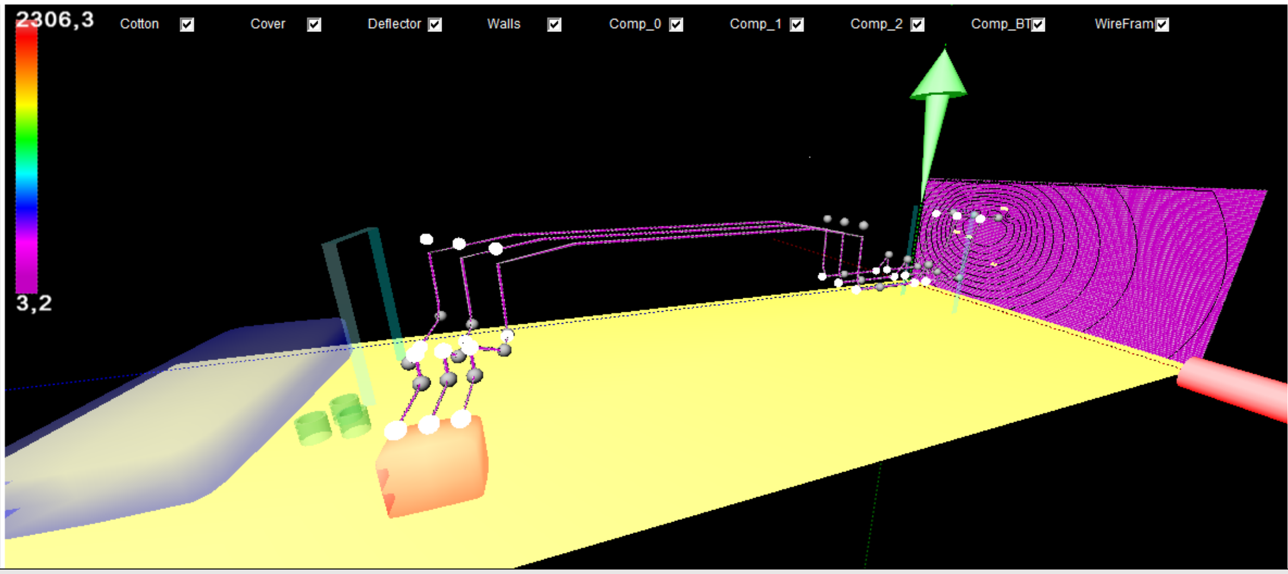
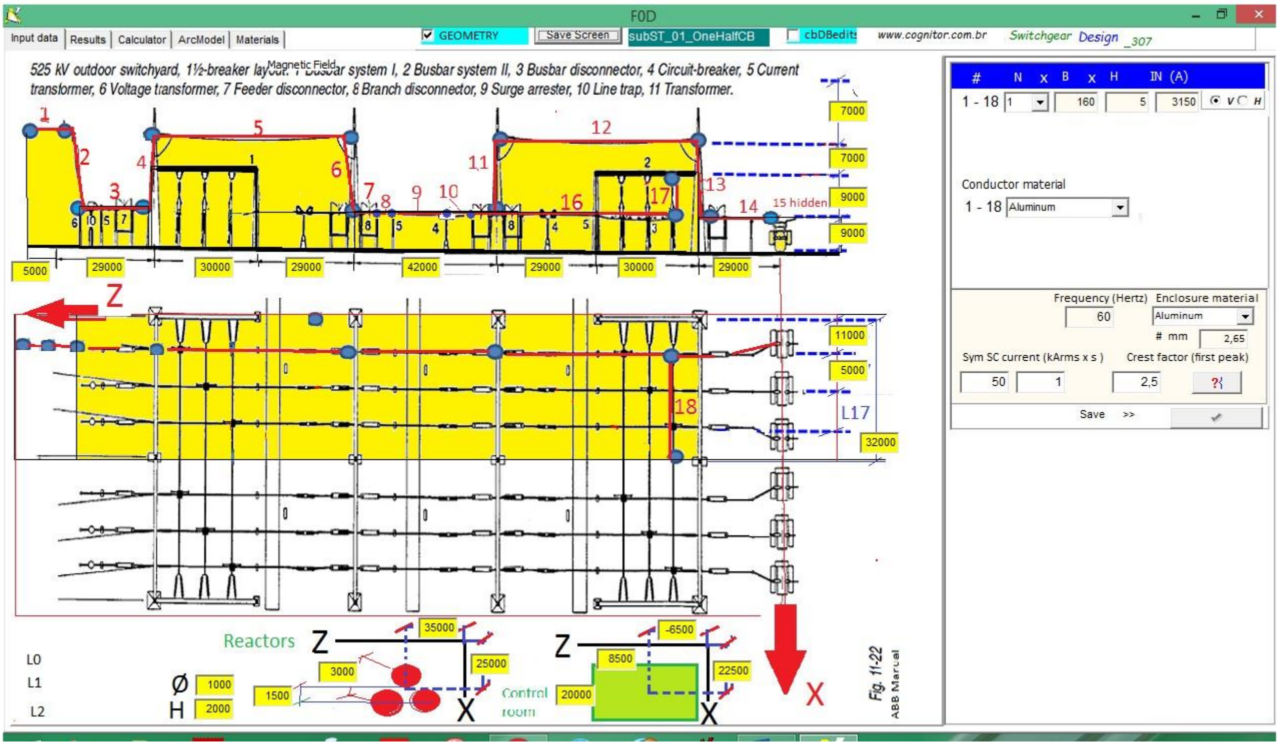


TABLE 16	ELECTRIC FIELD MAPPING	subST_01_ISI

Figure 15	ELECTRIC FIELD MAPPING
INPUT DATA AND RESULTS	subST_01_OneHalfCB



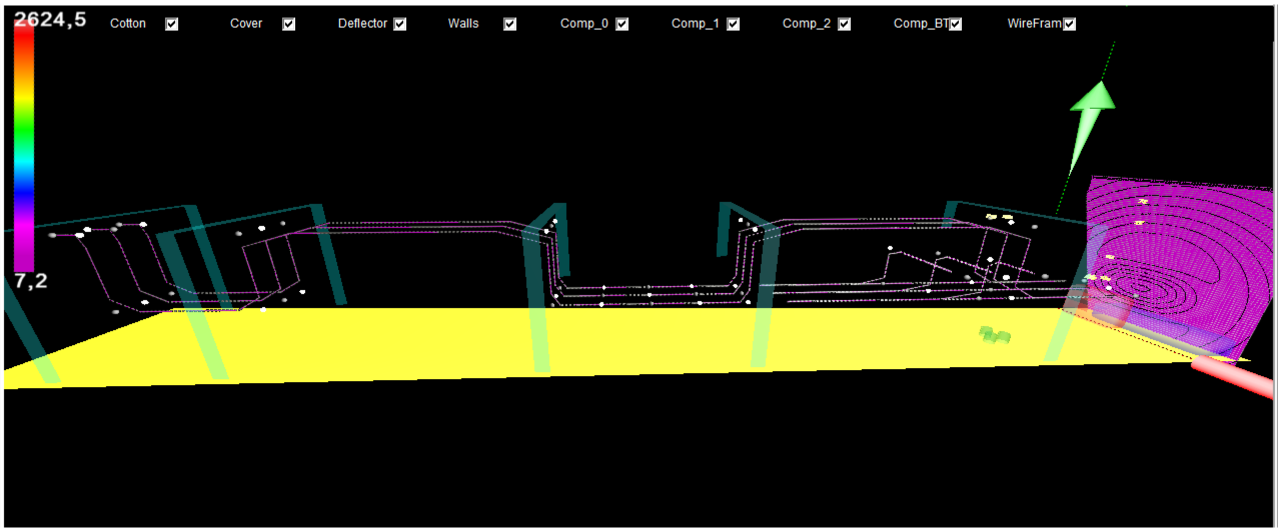


TABLE 17	ELECTRIC FIELD MAPPING	subST_01_OneHalfCB

Figure 16	ELECTRIC FIELD MAPPING
INPUT DATA AND RESULTS	MVSW1_02_M_R65111

xxxxxxxxxxxxxx

Xxxxxxxxxxxxxx

TABLE 18	ELECTRIC FIELD MAPPING	MVSW1_02_M_R65111

Figure 17 ELECTRIC FIELD MAPPING
INPUT DATA AND RESULTS Duct_R67131_3ph

xxxxxxxxxxxxxx

Xxxxxxxxxxxxxx

TABLE 19	ELECTRIC FIELD MAPPING	Duct_R67131_3ph

3. CRITERIA FOR ACCEPTANCE OF SIMULATION RESULTS.

See complete TR 71

4. REQUIREMENTS OF THE OPERATING SYSTEM

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

5. PROGRAMMING LANGUAGE

The software was developed originally in Delphi 7 (formerly Borland and now Embarcadero) and the most recent version is compiled in Delphi XE7

6. 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.

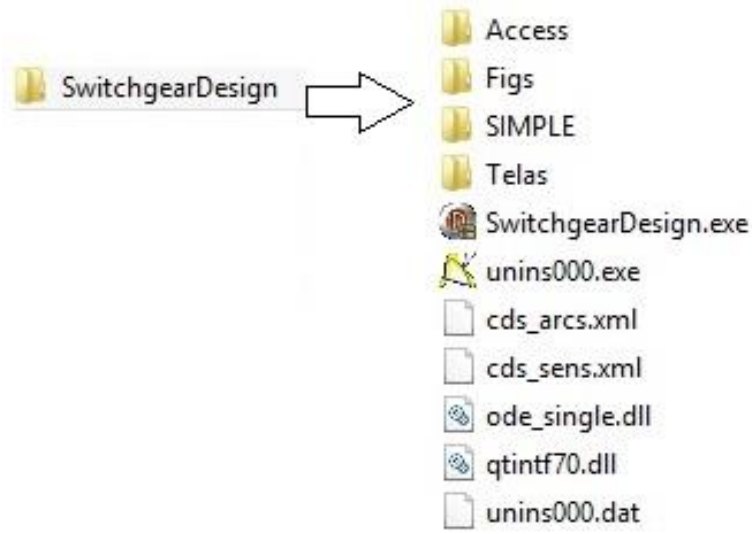
On your computer a single directory c:\SwitchgearDesign will be created where the all the necessary files will be installed.

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.

7. Annex A – REFERENCES (ARTICLES AUTHORED OR CO-AUTHORED BY SERGIO FEITOZA COSTA)

IN ENGLISH

[1] Report 074/2014 VALIDATION OF MAGNETIC & ELECTRIC FIELDS MAPPING & TEMPERATURE RISE TESTS SIMULATIONS.

http://www.cognitor.com.br/TR074ENGValidationTempRise.pdf

[2] Report 071/2014: VALIDATION OF SOFTWARE SWITCHGEARDESIGN_307 FOR SIMULATION OF HIGH POWER TESTS (TEMPERATURE RISE, SHORT TIME AND CREST CURRENT TESTS – ELECTRO DYNAMICAL FORCES / STRESSES AND OVERPRESSURES FROM INTERNAL ARC)

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

[3] Book “Reference text for the courses SWITCHGEAR, BUSWAYS & ISOLATORS and SUBSTATIONS AND LINES EQUIPMENT” (available also in Spanish and Portuguese in the site)

http://www.cognitor.com.br/Book_SE_SW_2013_ENG.pdf

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

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

[5] “VALIDATION OF SIMULATIONS OF ELECTRODYNAMICAL FORCES, TEMPERATURE-RISE AND INTERNAL ARC TESTS IN SWITCHGEAR (& main parts of a code) (2010)

Presented at the CIGRE Technical Seminar "Modeling and Testing of Transmission and Distribution Switchgear" March 24, 2010 Brisbane – Australia

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

[6] “SIMULATION, IEC STANDARDS AND TESTING LABORATORIES: JOINING THE PIECES FOR HIGHER QUALITY HV EQUIPMENT”.

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] "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 Congress Cigre - Paris 2008

http://www.cognitor.com.br/Cigre_Paris_A3_210_2008.pdf

[8] SIGNIFICANT PARAMETERS IN INTERNAL ARC SIMULATION AND TESTING,

CIGRE WG A3.24, CIGRE A3 SESSION, 2009

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

[9] Paper FINDING THE OPTIMAL SWITCHGEAR DESIGN: A comparison between aluminum and copper and an idea of new concept.

Co-authors: Sergio Feitoza Costa & Marlon Campos

Also published in Portuguese in January 2014 in Magazine Revista O SETOR ELÉTRICO "as ALUMINIO X COBRE EN PROYECTOS DE LOS PANELES ELÉCTRICOS (PÁGINA 136)

In English : http://www.cognitor.com.br/DesignOptimization.pdf

[10] HOW CAN IEC STANDARDS HELP TO REDUCE THE GAP BETWEEN DEVELOPED COUNTRIES AND OTHER COUNTRIES?

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

[11] VALIDATION OF TEST REPORTS ISSUED BY RECOGNIZED TESTING LABORATORIES

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

[12] SWITCHGEAR , BUSBAR SYSTEMS and ITS BUILT-IN COMPONENTS: SOMETHING IS MISSING IN IEC and IEEE STANDARDS

Published in Energy Pulse weekly, September, 28 , 2010

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

http://www.energypulse.net/centers/article/article_display.cfm?a_id=2338

[16] Free Software DECIDIX SOFTWARE FOR THE TECHNICAL ECONOMYCAL ASSESSMENT OF ENERGY PROJECTS

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

[17-25] Free for future use

EN ESPAÑOL - In Spanish

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

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

[27] VALIDACIÓN DE LOS INFORMES DE ENSAYO EMITIDOS POR LABORATORIOS DE PRUEBAS RECONOCIDOS

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

[28] Software libre DECIDIX para EVALUACIÓN DE LA VIABILIDAD DE PROYECTOS DE ENERGÍA

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

[29-33] Libre para uso futuro

EM PORTUGUES - In Portuguese.

[34] UM “GUIA” DE USO DE CALCULOS E SIMULAÇÕES DE ENSAIOS PARA AUMENTO DA COMPETITIVIDADE DA INDÚSTRIA ELÉTRICA

http://www.cognitor.com.br/Artigo_Competitividade_Port_04102011.pdf

[35] VALIDAÇÃO DE RELATÓRIOS DE ENSAIOS EMITIDOS POR LABORATÓRIOS RECONHECIDOS

Revista SETOR ELETRICO - Edição 82 - Novembro 2012 http://www.cognitor.com.br/ValidatingReports_Por.pdf

[36] PAINÉIS, QUADROS E BARRAMENTOS: FALTA ALGO NAS NORMAS IEC E NAS ESPECIFICAÇÕES DE USUÁRIOS

Publicado na edição de junho 2010 da Revista O SETOR ELÉTRICO - pág. 146

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

[37] VALIDAÇÃO DE SIMULAÇÕES DE ENSAIOS DE ARCO INTERNO, DE FORÇAS ELETRODINÂMICAS E DE ELEVAÇÃO DE TEMPERATURA (e partes do código-fonte) .

Junho 2010 da Revista ELETRICIDADE MODERNA - pág. 194

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

[38] SOFTWARE LIVRE DECIDIX para AVALIAÇÃO DA VIABILIDADE DE PROJETOS DE ENERGIA (GERAÇÃO, COGERAÇÃO e TRANSMISSÃO E DISTRIBUIÇÃO)

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

[39] Artigo publicado na Revista Setor Elétrico (Janeiro 2015)

Capítulo I – DEFINIÇÕES E ESTUDOS DO SISTEMA ELÉTRICO QUE SERVEM DE BASE PARA AS ESPECIFICAÇÕES TÉCNICAS DOS EQUIPAMENTOS PARA SUBESTAÇÕES DE TRANSMISSÃO E DISTRIBUIÇÃO

http://www.osetoreletrico.com.br/web/documentos/fasciculos/ed-108_Fasciculo_Cap-I-Equipamentos-para-subestacoes-de-T&D.pdf

[40] Artigo publicado na Revista Setor Elétrico (Fevereiro 2015)

Capítulo II – CURTOS-CIRCUITOS, AMPACIDADES SOBRECARGAS E CONTATOS ELÉTRICOS.

http://www.osetoreletrico.com.br/web/documentos/fasciculos/ed-109_Fasciculo_Cap-II-Equipamentos-para-subestacoes-de-T&D.pdf

[41] Artigo publicado na Revista Setor Elétrico (Março 2015)

Capítulo III : TÉCNICAS DE ENSAIOS DE ALTA POTÊNCIA, LABORATÓRIOS E FUNDAMENTOS DOS ENSAIOS

http://www.osetoreletrico.com.br/web/documentos/fasciculos/ed-110_Fasciculo_Cap-III-Equipamentos-para-subestacoes-de-T&D.pdf

[41] Artigo publicado na Revista Setor Elétrico (Abril 2015)

Capítulo IV: ESTUDOS ELÉTRICOS DE SOBRETENSÕES, COORDENAÇÃO DE ISOLAMENTO E IMPACTOS DE CAMPOS ELÉTRICOS E MAGNÉTICOS

http://www.osetoreletrico.com.br/web/a-revista/edicoes/1645-capitulo-iv-estudos-eletricos-de-sobretensoes-coordenacao-de-isolamento-e-impactos-de-campos-eletricos-e-magneticos.html

[42] Artigo publicado na Revista Setor Elétrico (Maio 2015)

Capítulo V: ARCOS INTERNOS EM EQUIPAMENTOS DE SUBESTAÇÕES

http://www.osetoreletrico.com.br/web/documentos/fasciculos/ed-112_Fasciculo_Cap-V-Equipamentos-para-subestacoes-de-T&D.pdf

[43] Artigo publicado na Revista Setor Elétrico (Junho 2015)

Capítulo VI: ESPECIFICAÇÕES TÉCNICAS DE DISJUNTORES, SECIONADORES, PAINÉIS E PARA-RAIOS FEITAS POR CONCESSIONÁRIAS DE ENERGIA

http://www.osetoreletrico.com.br/web/documentos/fasciculos/ed-113_Fasciculo_Cap-VI-Equipamentos-para-subestacoes-de-T&D.pdf

[48] Artigo publicado na Revista Setor Elétrico (Julho 2015)

Capítulo VII: DISTANCIAS DE SEGURANÇA DE SUBESTAÇÕES E SISTEMAS DE PROTEÇÃO CONTRA INCÊNDIOS EM SUBESTAÇÕES

[49] Artigo publicado na Revista Setor Elétrico (Agosto 2015)

Capitulo VIII: NOVOS CONCEITOS DO RELATÓRIO TÉCNICO IEC 62271-307 (PAINÉIS DE MEDIA TENSÃO)

[49] Artigo publicado na Revista Setor Elétrico (Setembro 2015)

Capitulo IX: TÉCNICAS PARA AUMENTAR A CAPACIDADE DE PAINÉIS E BARRAMENTOS EXISTENTES ADIANDO INVESTIMENTOS NOVOS.

[50] Artigo a publicar na Revista Setor Elétrico (Outubro 2015)

Capitulo X: INDUZINDO NOVAS TECNOLOGIAS PARA O SETOR ELÉTRICO

[51] Artigo a publicar na Revista Setor Elétrico (Novembro 2015): Capítulo XI: título a confirmar

[52] Artigo a publicar na Revista Setor Elétrico (Dezembro 2015): Capítulo XII: título a confirmar

8. 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

9. Annex D – COMPARISON WITH TEST REPORTS.

REPORT 67752 – TEMPERATURE RISE TEST

67752 - Calentamiento

FOLHA

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Av. Prof. Luciano Gualberto, 1289 - Cidade Universitária - Butantã
CEP 05508-010 - São Paulo - SP
Tels.: (11) 3091-2527 / 3091-2528 - Fax: (11) 3032-7750

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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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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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.

UNIVERSIDADE DE SÃO PAULO
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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

FOLHA

UNIVERSIDADE DE SÃO PAULO
INSTITUTO DE ELETROTÉCNICA E ENERGIA

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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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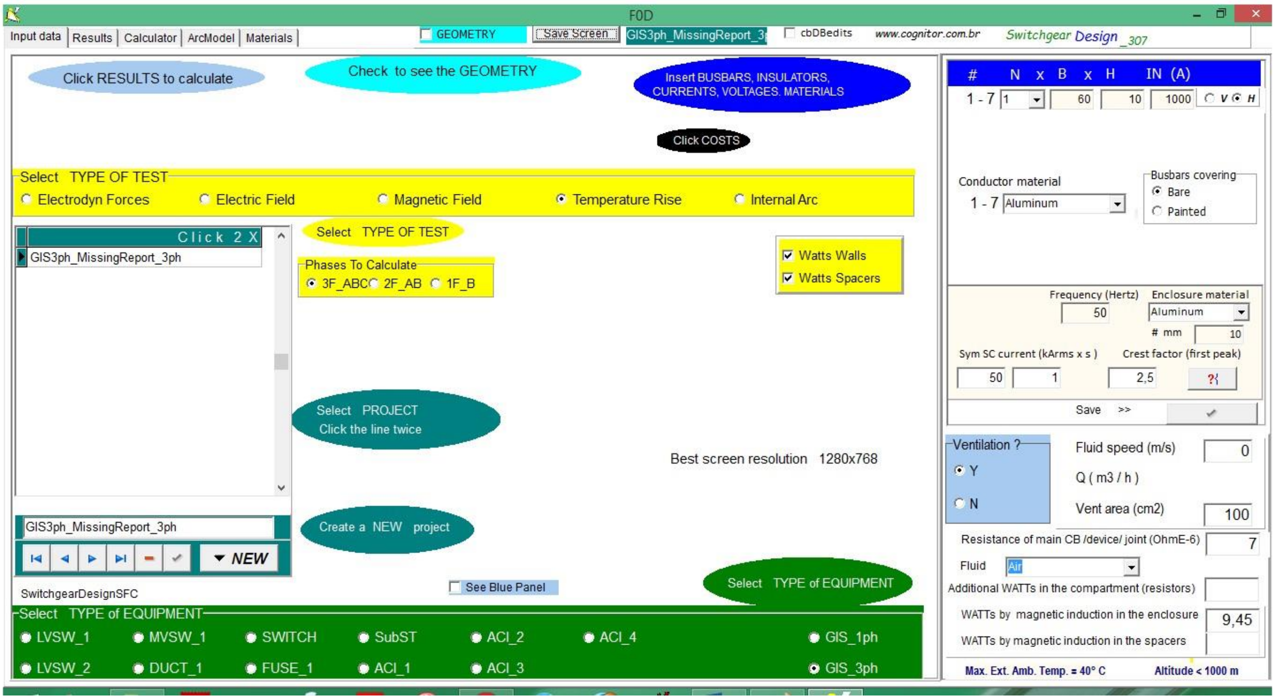
RELATÓRIO OFICIAL Nº: 67131

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

10. Annex E - TYPES OF CALCULATION WHICH ARE POSSIBLE WITH SWITCHGEARDESIGN_307 (yellow bar) AND TYPES OF EQUIPMENT (green bar)



GREEN BAR

LVSW_1 : Low voltage switchgear - compartment with circuit breaker

LVSW_2: Low voltage switchgear - drawers bars

MVSW_1; medium voltage AIS

DUCT_1: Bus duct LV or MV

SWITCH: isolator FUSE_1: MV or LV fuse

SubST, SubstISI, ,Subst_2 - substation arrangements

ACI_1 and ACI_2 - MV voltage switchgear

ACI_3 and ACI_4 - LV voltage switchgear

GIS_1ph - GIS SF6 single bar and GIS_3ph - GIS SF6 Three phase

11. Annex F - TECHNICAL STANDARD (GUIDE) FOR THE APPLICATION OF SIMULATION TO REPLACE SOME LABORATORY TESTS

11.1 – Introduction

This text was prepared in 2010 by Sergio Feitoza Costa, as a formal proposal for IEC and to the Brazilian National Standardization Committee to be the basis of a new Standard. Although the proposal had the support of around 25 relevant companies, the BNSC decided not to do the standardization work. Now, 5 years later, the concepts showed in this text are now referred or used in Cigré publications and in IEC standards as IEC 62271-307 .

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 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 testing, services using simulations. To build a large laboratory cost more than fifty hundred million dollars and that is why the tests are expensive. As a private business is not always 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 their differential to develop own products using many simulations combined with tests. 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 to follow. Here we call this "future" standard of SIMULATIONS APPLICATION GUIDE (Guide).

The reader 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 as a formal standard, an interesting action for many countries is to establish a commission in their National Standards Association to implement it. An example of action of this nature is in Colombia where it was implemented a government regulation that allows, under certain conditions, the use of calculations and simulations.

12.2) 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 useful 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.

The brochure CIGRE WG A3.24 "TOOLS FOR THE SIMULATION OF EFFECTS IN INTERNAL ARC MV AND HV SWITCHGEAR "was published in 2014 after a work started in 2009. 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 of the testing laboratories do not perform measurements not requested in the technical standards, whether simple to do. However, some do it 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.

12.3) 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.

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

A model or method is acceptable if produces simulation results within acceptable tolerances, if compared with the real test results and this is 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 smaller and 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.

12.4) SOME DEFINITIONS (of the Simulations Application Guide)

12.4.1 – 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

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

These tests check 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.

12.4.3 – 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.

12.4.4 – 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%
Magnetic and electrical field mapping	Module and XYZ components of the field at any point	5%

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.

12.4.5 – 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).

12.4.6 - 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.

12.4.7 - 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.

12.4.8 - 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.

12.4.9 - 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,

12.4.10 - 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 verified 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.

12.5) 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.

12. Annex G - SOFTWARE SwitchgearDesign_307: USER REQUIREMENTS, INPUT and OUTPUT DATA, TRAINING AND CONDITIONS OF USE

The software was created 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, 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).
- Internal arc test (calculation of overpressure, burnthrough and supportability)
- Temperature rise tests.
- Mapping of electric and magnetic fields.

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 and electric field	Yes
Module MVSW1 (medium voltage)	Yes
Modules LVSW1 e LVSW2 (low voltage)	Yes
Module DUCT_1 (busways)	Yes
Module SWITCH (not validated)	Yes
Module GIS_1ph and GIS_3ph	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 – Read Section 1

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 parts of sheets of test reports made in testing laboratories. There are also pages of other publications useful for validation purposes. Parts covered by black marks are intentionally hidden to avoid identification of names.