EDUCATION is the key

TEMPERATURE RISE LIMITS used in I E C / IEEE S W I T C H G E A R STANDARDS

Is it possible to increase them at least 10degrees to save copper, aluminum and other Planet's resources?

As was done with EMC, all IEC standards should include a "STATEMENT" such as: " Products covered by this standard use significant amounts of copper, aluminum, insulators, and metals. Material savings are desirable for the Climate Change and Energy Transition initiatives. Products with designs that passes on the type tests and achieve lower values of weight.by transmitted power (kg/MVA) are encouraged and considered environmentally better".

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Abou the Author

Sergio Feitoza Costa is a composer, musician, writer, and electrical engineer. Alongside a successful career of 45+ years in electrical engineering R&D, has parallel activities with music production and fiction books writing.

At the age of 70, Sergio spent the first part of his career working on setting up research centers and high-power electrical test laboratories and helping to write IEC technical standards. After that Sergio had a challenging performance in the energy sector collaborating in the implementation of large renewable energy programs in Brazil. He has also participated on government programs for non-renewable energy.

Applied for many years training and consulting work in assessing technologies and costs of energy projects. For the past 20 years has worked helping manufacturers to develop substation equipment. Created a unique tool to simulate expensive high-power tests.

- **Things Sergio helped to do and CV**

https://www.cognitor.com.br/HelpedToDo.pdf https://www.cognitor.com.br/Curriculum.html

In these links you may find Sergio's free books and articles.

There are others in the site www.cognitor.com.br

- Book "Switchgear, Busways & Isolators and Substations & Lines Equipment"

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

- Book "Project Save Rio in 10 years " https://www.cognitor.com.br/saverioENG.pdf
- Book "The Cosmic Engineers in the Land of Amazonia":

https://www.cognitor.com.br/TheCosmicEngineers.pdf

- Book Renewable Energy + Environmental Education to try to save the Planet

https://www.cognitor.com.br/educationfortheplanet.pdf

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- Songs production

https://www.cognitor.com.br/MusicSergioFeitoza.html

https://www.youtube.com/user/SergioFeitoza/

This book is dedicated to my grandson and friend Augusto who made me want to live some more years on this beautiful and challenging Blue Planet.
I hope that his generation will find a way to stop the Earth destruction.

It's unbelievable how we cannot stop wars and the fast degradation of the environment. The meaning of my song "Atlantis Again" is already materializing.

CONTENTS

1. ABOUT THE CONTENTS OF THIS BOOK

I wrote this book in my 70s to record and to register some ideas that I have been sharing in articles and publications. Most of these ideas are taking shape, step by step, and are somehow connected to the application of my electrical engineering knowledge to develop more efficient products that use less materials and Planet's resources. Other books I wrote about the theme are listed and freely accessible in the links along this text.

With this book I am cleaning my desk and recording ideas for posterity. I started this 2 years ago with a patent and many good quality trainings and articles posted "for free" on LinkedIn. They reach many more people than paid publications, even the high-quality ones.

I hope that, in this life, this will be my last book in the area of electrical engineering and energy sources. My intention is to dedicate more and more time to write fiction books and to composing songs. The engineering moments will be smaller and focused only on applying training to the younger ones. It is a way of trying to open the minds, so that they do not make as many mistakes as my generation. Engineers with a serious and reasonable environmental and social vision are increasingly rare. I still see today, while the Planet is going straight to destruction, young and older experts concerned in rediscover the wheel like calculating the transient recovery voltage or selling low-quality technical articles on the Web. This is very visible even in the work of the top voices of the electrical sector.

> The ideas I present in next pages, are not difficult to accomplish. A barrier is that they are largely dependent on the actions of the big and accommodated companies that push the worldwide electric industry. Not necessary to list their names. They have enormous capacity for achievement, they made the electrical industry advance a lot 50-60 years ago, but after, they have become lazy and averse to innovations that take them out of the comfort zone of their high profits. The beautiful environmental speech, in marketing campaigns, does not correspond to what they could do in the short term, in the sense of setting good examples for the World.

An example is in big technical standards institutions like IEC and IEEE. They are managed by the top management of major worldwide manufacturers and only projects that interest them move forward. Initiatives that involve creating alternatives to increase the efficiency of older technologies that have already been tested, and are sold worldwide, do not move forward. Right here in this book I show examples. One of them is the issue of increasing temperature rise limits, main focus of this book.

Another example is the issue of the dangerous proximity of distribution transformers that can explode from windows and buildings with children and laypeople. Power utilities and standardization bodies pretend not to see the problem that I describe in Annex B.

In a certain way, it is the same reasoning as the major world economies that have come together since 1992, at Rio 92, to take environmental actions that have always been postponed until two years later. Floods, hurricanes and hungry populations evacuated from

war zones are increasing rapidly under the patient look of entire populations with a very low level of education, even to know how to complain and vote.

We see in the TVs that instead of applying money to reduce world hunger and environmental problems, the most powerful nations are proud to say that are selling weapons to feed wars. This has destroyed the necessary credibility of societies, that there would be leaders who really wanted to solve the problems. I can't see any that have this credibility. Even the simplest common citizen notices the theatrical moves

> We need good examples of serious initiatives like making mandatory that in IEC and IEEE technical standards, statements saying that higher efficiency and lower use of materials is good. Try to find just one technical standard mentioning this.

A strong contribution to stop the Planet from collapsing quickly is to regularly showcase positive, instructive visible models in the day-to-day practices of developing nations. An example is educating more people about the value of preserving materials and Earth's resources. For instance, the electric power sector uses a lot of materials that are obtained from mining, like copper.

As said, the existing IEC, IEEE and other technical standards simply do not mention or signalize that more efficient designs using less materials is desirable. The standards are focused only on severe and expensive tests to verify the performance.

Recently I read an article of the International Energy Agency (IEA) about the lack of access to “clean cooking” which affects over 2 billion people worldwide. Cooking with charcoal, wood, agricultural waste, and animal excrements, produces toxic fumes and is the second leading cause of premature death in some regions.

> In that text, I saw a comment about the market for critical minerals that go into electric vehicles, wind turbines, solar panels and other clean energy technologies. The text was about **“energy transition minerals”, such as copper, nickel, lithium, cobalt, graphite and rare earth elements**. Demand for critical minerals continues to grow strongly, driven by the deployment of clean energy technologies.

The concerns of most Planet's technical minds do not usually look at details like these because think that saving materials are secondary issues that will not help save the Planet.

> Instead of seeing most of G7 countries gaining money selling weapons for wars we need to witness serious efforts to minimize the effects of climate change or to reduce hunger. Note that whenever a leader touches on problems such as hunger or unnecessary killings, the G7 leaders remain silent or create some way to disqualify the criticism.

If you want to understand what I'm talking about, read the news about the opening speech by the Brazilian president at the (2024) 79th UN General Assembly. Also read the criticisms that came afterwards.

In this book the main focus is in showing the relation between the temperature rise limits of materials used in the electrical industry and the saving of materials which is possible **if the limits presented in IEC standards can be increased.** I proposed to CIGRÈ (A3 and B3 subcommittees) to investigate the theme but so far it has not aroused the interest of the majority enough to form a working group. Check description of the **proposal in Annex A**.

Also, I included in **Annex B** another **proposal sent to CIGRÈ** for the creation of new work about "distances between cables of urban distribution lines and windows of residences". The matter is about risks to persons not covered by the relevant IEC standards. Just take a look in this article and video to understand. We have in Brazil technical standards not based in an international standard, made by power utilities, that do not consider risks of explosions of distribution transformers and expulsion fuses near lay people.

Article: https://www.cognitor.com.br/FusesInTheWindows.pdf

Video: https://www.youtube.com/watch?v=dra1zBg9OuE

More than this. I included in **Annex C a** suggestion to IEC and IEEE for a technical standard related to **"Guidelines for The Use of the "Environmental Efficiency Certificate of Electric Products".** It is about a way to insert in technical standards an indicator of design efficiency in terms of kg/MVA transmitted.

In **Annex D** there is a complete **free training and lecture** on switchgear, switchboards, panels, busducts of IEC_62271-200 / IEC_62271-307, IEC_61439

In the **Annex E** I register an idea to reduce the size of AIS switchgear up to 38kv using a **mixed AIS + Triaxial GIS solution with non-SF6 gasses at low pressure**.

ABOUT REASONS TO TRY TO INCREASE TEMPERATURE RISE LIMITS IN IEC STANDARDS

Because technical standards do not even bring up the idea that saving materials is better, we waste like 30% of copper, aluminum and others used to manufacture from small circuit breakers used in residences to big power transformers of power substations. In the middle, are the electric panels, switchgear and switchboards covered by standards series IEC 61439 and IEC62271. A market of hundreds of billion Euros is not a narrow matter.

A point to have clear in mind is that low voltage and high voltage electric panels use the same materials, design principles, the same tests and have the same basic functions. **Except for the nominal voltage, there is no difference between both panels.** Medium voltage switchgear panels transmit something like 15x more energy and their technical standards are more transparent and safer than the low voltage standards.
Then, for example, if someone wants to use IEC62271-307 to extend the validity of a test report of tests done by IEC 61439 series (low voltage) is not doing nothing wrong. Conservative people who don't like to deviate even a bit from old habits may say that low voltage switchgear have nothing to do with medium voltage panels. If they say this, they are technically wrong and have little understanding of switchgear design techniques.

The higher the voltages, the greater are the dielectric and internal arc requirements. However, for temperature rise aspects there no difference. They depend only on currents and do not depend on the voltages.

A good reference to understand saving materials concepts is the Cigrè brochure 740 (2018) named “Contemporary solutions for low-cost substations”. I am coauthor of this document that provides to experts of developing countries, an array of possible solutions for the design procurement and establishment of substations, enabling them to embrace the United Nations vision of “Electricity for all by 2030”.

"Failure to mitigate climate change" is one of the primary issues, according to the World Economic Forum 2022. The **"crisis of natural resources"** is ranked fifth and has direct connection to the Energy Transition initiatives. Better sound examples to follow can be provided by the electric power sector.

IEC and Cigrè are two global voices of the electric power sector. Their prominence makes it easier to highlight sensible real-world examples that go toward protecting the environment. As of now, technical standards do not promote or signal the use of aluminum, copper, and other materials in smaller quantities. Standards for the creation and usage of products are still focused on approval through rigorous testing, just as they were fifty years ago when climate change was not a concern. Positive statements on climate change these days must be supported by visible educative actions that goes beyond commercial marketing showing wolves in sheep's clothing.

In 2024 I prepared and sent a suggestion to Cigrè A3 and B3 about assessing the relevancy of changing temperature rise limits used in IEC standards. **The estimated final result of this, in my view, could be savings of copper and aluminum around 30% in weight of current values**. As Cigrè, after one year, still did not make the idea in Annex A to advance, I am making available here the (free) relevant information to whom wants to use it.

This delay in realizing the relevance and environmental benefits of saving materials is of the same nature why IEC standards do not encourage or even mention that saving of resources of the Planet is important. The minds of many experts have stopped in time and still think that the only important thing is to be approved in the expensive and severe laboratory tests.

In short words the idea is the following:

Temperature rise test and temperature limits within product standards define equipment design and weights of product, specially the conductors. With the available experience and simulation capabilities of today, these limits could be verified to be able to establish new higher limits to enable less use of materials.

As explained after, in this text, each 10 degrees (K) increase in the temperature rise limits may represent some 30% of savings in conductor materials like copper and aluminum.

The objective of the work proposed by me is to assess if the temperature rise limits used in IEC and IEEE standards could be increased and by how much. The steps of the work would be:

- Raise the history that led to the limits used today within IEC and IEEE (consultations to experts and documentation). To clarify the duration of useful life they were associated with.

- Survey the R&D activities that have been carried out recently and that can bring evidence to propose raising the current limits (questionnaire & consultation with experts of IEC, IEEE, etc...)

- Survey of the existence or not of systematic problems with aspects of temperature rise. Focus on switchgear and T&D above 1 kV equipment. If there are few problems possibly limits can be increased (questionnaire)

- To make a proposal for limit values for “Synthetic OG” beside “OG” and “NOG” as oxidation is favoured by high humidity, high temperatures and presence of catalysts and presence of impurities or pollutants that can act as catalysts.

- If the results are positive, to make a proposal for IEC and IEEE standards modifications.

- To write a brochure including the conclusions of the work. In the results, to indicate the positive and negative impacts of increasing the temperature rise limits by 10K or 15K or 20K or more.

Another suggestion in the direction of promoting the importance of higher efficiency is about the general focus of technical standards. It is disappointing to note that even now, in the times of beautiful green speeches, the IEC, IEEE and national technical standards do not give any importance to encouraging, rewarding or inducing the economy of resources and greater efficiency in the manufacturing of electrical products.

An effective way to do a serious action in this direction would be to include a mandatory statement in all IEC / IEEE product standards indicating that using less copper, aluminum, and insulators is good for the environment and that IEC standards encourage this.

> **This "mandatory statement" to include in all products standards could be like:**
>
> Products covered by this IEC / IEEE standard use significant amounts of copper, aluminum, insulators, and metals. Material savings are desirable for the Climate Change and Energy Transition initiatives.
>
> Products with designs that passes on the type tests and achieve lower values of weight by transmitted power (**kg/MVA**) are encouraged and considered environmentally better.

The implementation of the statement would be like was done by IEC in the 80's to promote the importance of EMC (electromagnetic compatibility).

It became mandatory that IEC technical standards should have a clause talking about the susceptibility or not of that product with EMC.

Possibly behind that idea were concerns about future cyber-attacks and things of the same nature. Implementation was immediate.

2. WHAT IS THE TEMPERATURE RISE TEST AND THE LIMITS USED TO BE APPROVED OR NOT ?

Technical standards for electrical products specify tests to demonstrate the proper performance of products. The "temperature rise test" is included in most of them. It is used to verify if the working temperatures are lower than the values that would produce a faster aging of materials. There are also other verifications as the temperatures reached by enclosures that could be touched and hurt the hand of persons like operators or lay people.

In the test you apply the test electric currents, wait for temperature stabilization and measure the temperatures in some key points.

The equipment pass on the test if the temperature rise in the key points are lower than the limits specified in the technical standard. The values of these limits are the key for materials savings.

Depending on the materials and coatings used, higher or lower temperatures are permitted to avoid faster ageing of connections or contacts. The limits of temperature rise are specified in the technical standards tables like this one

Table 3.1 (part of **Table 14 of IEC 62271-1** (2017)) – **Some limits of temperature rise for various parts, materials and dielectrics of high-voltage switchgear and controlgear**

Nature of the part, of the material and of the dielectric	Maximum value	
	Temperature °C	**Temperature rise at ambient temperature not exceeding 40°C** **K**
Contacts		
Bare-copper or bare-copper alloy		
- in OG	75	**35**
- in NOG	115	**75**
- in Oil	80	**40**
Silver-coated or nickel-coated		
- in OG	115	**75**
- in NOG	15	**75**
- in Oil	90	**50**
Tin-coated		
- in OG	90	**50**
- in NOG	90	**50**
- in Oil	90	**50**
Connections, bolted or the equivalent		
Bare-copper or bare-copper alloy or bare-aluminium alloy		
- in OG	100	**60**
- in NOG	115	**75**
- in Oil	100	**60**
Silver-coated or nickel-coated		
- in OG	115	**75**
- in NOG	115	**75**
- in Oil	100	**60**
Tin-coated		
- in OG	105	**65**
- in NOG	105	**65**
- in Oil	100	**60**
Terminals for the connection to external conductors byscrews or bolts (refer to points 8 and 14)		
- bare	100	**60**
- silver or nickel coated	115	**75**
- tin-coated	105	**65**
Accessible surfaces		
Surfaces of manual control components to be touched in normal operation:		
- Uncoated metal	55	15
- Coated metal	55	15
- Non metal	65	25
Other surfaces to be touched in normal operation but not to be held continuously in the hand:		
- Uncoated metal	65	25
- Coated metal	70	30
- Non metal	80	40
Surfaces not to be touched in normal operation:		
- Uncoated metal	80	40
- Coated metal	80	40
- Non metal	90	50

The best world document to understand the principles is IEC TR 60943:1998 - Guidance concerning the permissible temperature rise for parts of electrical equipment, in particular for terminals.

The document is intended for guidance in estimating the permissible values for temperature and temperature rise of component parts of electrical equipment carrying current under steady state conditions.

The report is intended to supply:

- general data on the structure of electric contacts and the calculation of their ohmic resistance.

- the basic ageing mechanisms of contacts.

- the calculation of the temperature rise of contacts and connection terminals.

- the maximum "permissible" temperature and temperature rise for various components, particularly the contacts, the connection terminals and the conductors connected to them.

- the general procedure to be followed by product committees for specifying the permissible temperature and temperature rise.

Relatively few people know this document. I heard from its haying existence in the late 1980s when I coordinated the IEC Technical Committee 32 (FUSES).

After knowing I studied and divulged it a lot within IEC and CIGRE working groups I participated.

Now this document is referred in important documents like IEC62271-307 [Ref. 2] and Cigrè Brochures 740 [Ref. 5] in which I am also coauthor.

For the test, 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 the mentioned limits.

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.

This part of table extracted from IEC62271-307 for the extension of the validity of test reports enables us to understand the key design factors for temperature rise tests.

Follow table from IEC TR 62271-307 (Extension criteria for temperature rise performance)

Table 2.1 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 1 250 A (see IEC 62271-1:2007, 6.5.2)
2	Phase to earth distance	≥	Only to validate if an influence on the surrounding elements due to currents cannot be excluded, e.g., eddy currents and magnetising currents.
3	Enclosure/compartment dimensions (L,H,W) and volume	≥	The enclosure and compartments are of the same construction.
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 3
11	Power dissipation of components	≤	Here the main switching devices, fuses and current transformers are considered.
12	Area of insulating barriers	≤	Barriers have the same physical arrangement
13	Thickness of insulating coating of conductors	≤	Thermal resistivity and emission coefficient of the coating should be the same.
14	Total coated surface area of enclosure for heat transfer	≥	The emission coefficient of the coating should be the same.
15	Temperature class of insulating material in contact with conductors	≥	

3. WHY THE TEMPERATURE RISE LIMITS SPECIFIED IN TECHNICAL STANDARDS DEFINE THE AMOUNT OF MATERIALS TO BE USED IN AN EQUIPMENT DESIGN ? WHY HIGHER LIMITS COULD ENABLE LESS MATERIAL USE.

The "Temperature Rise Test" determines the conductor weight of materials used in product design. If the limits that you cannot go above are lower, you need to use more conductor material to maintain the temperature. If the limits are higher, you can use less material.

Switchgear of any voltage, such as the products of IEC61439 and IEC 61271 series, are the easiest items of a substation to understand the reasons for this. This also holds true from small substation busbars to large power transformers.

> Substations and T&D lines equipment employ the same materials at low voltages as well as ultra-high voltages. **The connections between busbars and to other components, such as circuit breakers and disconnectors, are typically the "hot spots" that indicate whether or not the product will pass the temperature rise test.**

The main factor affecting the temperature rises are the local resistances. High gains in lowering rises are made possible by additional factors like improved ventilation and design tricks as using busbars 2x100x5mm rather than the same weight 1x100x10mm, just because the area exposed to cooling is higher. Easy to understand and to do but still, the designs of 50 years ago, made in the time of fat cows, prevails in the market. Most products could use less materials.

> In the past it was common to over dimension products to pass the expensive tests in the first time. Nowadays you can easily use computer testing simulations to do in 30 minutes what would take more than 1 testing laboratory day.
>
> Just one day of testing may cost between USD 3000,00 to U$10.000,00. I learned this in real life working 25 years in big testing laboratories and more some 20 years developing and using the testing simulator SwitchgearDesign.

The geometry and materials, not the product's voltage, determine how much a hot spot can rise in temperature. Table 14 of IEC62271-1, for instance, specifies values such as 60K for bare connections and 75K for silver or nickel-coated connections. Staying below the limits is the test's goal. As said, the use of materials decreases if you use a higher limit because you can use smaller conductors cross-section and still stay in the limits.

> The busbars could be constructed with less weight if it were possible to employ temperature rise limits higher than those in use nowadays. The bar heats up more if it is thinner. If allowed limit goes up, we use less material passing the test. If the limits we use today were just raised by 10 to 15K, this would result in a 25–35% decrease in weight.

Possibly a lot of R&D work has been conducted in the previous fifty years. It is difficult to find bibliography to understand how the temperature rise limits were established in the past and whether the information available today would enable their desired increase. This is what we proposed to do in the work described in Section 1.

In order to use less materials, we must push beyond our comfort zones. Experts participating in the "IEEE Holm Conference on Electrical Contacts" may have a lot of knowledge that can be used to make the idea exposed in this book to advance.

Possibly the “old products specifications” are associated to a useful life higher than 40 to 50 years. This is not good because nowadays technologies and goals change in less than 15 years. It is necessary to have clear in mind the duration of time life we expect from the component.

> IEC TR 60943 enables to calculate aging when equipment is used above the limits (that we want to increase). To attend the rising of temperature rise limits we propose in this book, we need to estimate how much we can increase the limits of temperature rise for a time life like 25 or 30 years maximum. The knowledge about materials increased in the last 50 years. There is a clear indication that limits can be increased based on the use of temperature rises of 85K instead of 75K (IEC62271-1) in silvered connections of low voltage switchgear (IEC61439-1)

Some of these aspects were touched in Cigrè brochures 830 (2021 – simulation of temperature rise), brochure 830 (2021 – low-cost substations) and 602 (2014 – simulations internal arc). As explained on them, we have in our favour the fact that, we do not need to go to testing labs to do verifications, except some few.

The testing simulation techniques and tools available nowadays enable to do fast simulations of temperature rise tests in substations products without needing complex CFD models.

Check in the next figure and table the estimate of different weights of copper necessary to design a MV switchgear 17,5 kV – 1250 A as a function of the permitted temperature rise and power dissipation of the circuit breaker.

The circuit breaker is in conductors #3 to #5. They are the hot spots. We explored 3x4 combinations of temperature rise limits and power dissipations.

The reader can see clearly the savings of materials which are possible just by increasing the temperature rise limits which will be used to state if the equipment passed or not in the test.

To increase these limits in the standards we need to prove that the useful time life associated with them are within an acceptable range.

Not something like 70 years because is so much for a switchgear.

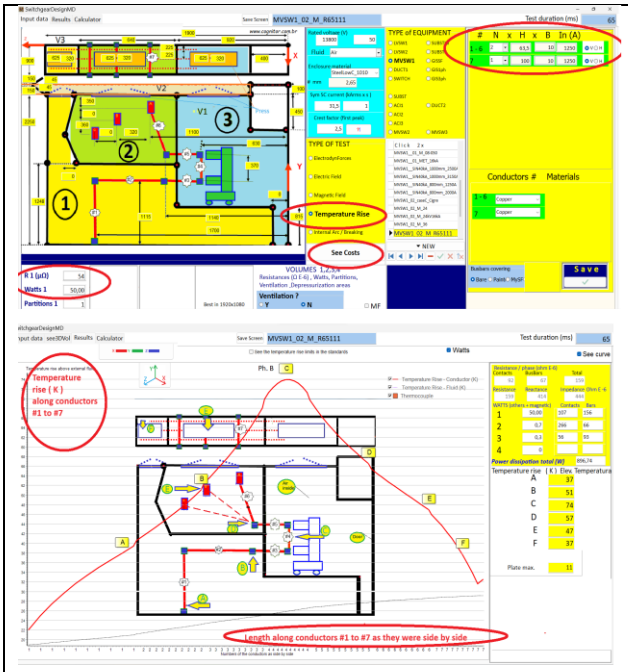
But also, not so low as 10 years because it is expected an order of magnitude of some 20 years

Very possibly, the limits written in the technical standard IEC62271-1 are associated with a time life higher than some 50 years.

This was the practice 5 decades ago. Time has passed and it seems that those who make the IEC and IEEE standards no longer invest in updating the values.

This became important now if we are speaking serious in the actions to save the Planet.

Figure 3.1 - Busbars to use and % of weight X Temperature rise limit



Temperature rise Limit (K)	Bars (and weight) to use as a function of permitted temperature rise power dissipation of main circuit breaker 3ϕ (Watts) obtained from the "resistance per phase as seen from the terminals"		
	150W	**300W**	**600W**
60K (bare)	**1 x 160x10** (50%)	**2 x 160x10** (100%)	**2 x 250x10** (156%)
75K (silvered)	**2 x 120x10** (75%)	**2 x 140x10** (87%)	**2 x 160x10** **(100% weight)**
85K	**1 x 150x10** (47%)	**2 x 80x10** (50%)	**2 x 120 x 10** (75%)
105K	**1 x 100x10** (31%)	**1 x 110x10** (34%)	**2 x 80 x 10** (50%)

4. OTHER STEPS TO ASSESS IF THE TEMPERATURE RISE SPECIFIED IN TECHNICAL STANDARDS CAN BE INCREASED

As mentioned in the proposal done to Cigrè (Annex A), the questions to be answered to assess if the temperature rise limits used in IEC standards – for connections and contacts (only) - could be increased and by how much should follow steps more or less like this:

a) To raise the history that led to the temperature rise limits used today through consultations to experts and documentation.

This activity can be done by consultations with experts and documentation. These experts are possibly the older professionals still in activity. Work on the R&D bibliographies is needed. In a first view access to relevant documents is limited. It is desirable to create a historical step by step to observe the evolution of values over time.

I suppose that experts in contact with the "IEEE Holm Conference on Electrical Contacts" may have a lot of knowledge that can be useful.

b) To clarify the duration of useful life they were associated with the temperature rise limits used today.
c) Survey the R&D activities that have been carried out recently and that can bring evidence to propose raising the current limits (worldwide questionnaire and consultation with experts in IEC, IEEE, etc...)
d) Survey of the existence or not of systematic problems with aspects of temperature rise. Focus on switchgear. If there are few problems possibly limits can be increased (questionnaire)
e) To write a document including in the conclusions a clear indication of the positive and negative impacts of increasing the temperature rise limits by 10K or 15K or 20K or more

To have credibility a task like this is to be conducted by a working group in Cigrè or other institution which consider saving Earth materials important.

Although I have opinions about each of the steps, I will not write about them here.

5. FINAL COMMENTS

Here are the proposals. More details are in the Annexes

I tried to keep this text short. I understand that this issue of temperature rise limits has a considerable impact on the weight of equipment and expenses with materials such as copper and aluminum.

Specialists who do not deal directly with design aspects and their relationship with economics will have more difficulty understanding why savings are possible.

This text contains the necessary explanations to understand the problem.

For all the work I have been involved in at IEC and CIGRÈ, I would place this issue at the top of the list of priorities.

I am sure that experts participating in the "IEEE Holm Conference on Electrical Contacts" and the ones which are near the themes of IEC 60943 have a lot of knowledge that can be used to make the idea exposed in this book to advance.

If it is not a matter of the interest of Cigrè subcommittees A3 or B3 maybe can be of the interest of Group D1 - Materials and emerging test techniques

I do not have contacts there but certainly the management of Cigrè have and can at least check.

REFERENCES

[1] IEC 62271-1 High-voltage switchgear and controlgear. Part 1: Common specifications

[2] IEC TR 62271-307:2015 - 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

[3] IEC TR 60943:1998 - Guidance concerning the permissible temperature rise for parts of electrical equipment, in particular for terminals

[4] Edgar Dullni - Continuous Current Conduction and Long-Term Performance of Bare and Coated Contacts at High Temperatures - IEEE switchgear meeting 2016-04-28

[5] Brochure Cigrè 740 (2018) - Contemporary design of low-cost substations in developing countries

[6] Brochure Cigrè 830 (2021) - Application and Benchmark of Multiphysics Simulation Tools for Temperature Rise Calculations

[7] Feitoza Costa, S.., " Free Book Switchgear, Busways & Isolators / Substations and Lines equipment (Reference book for training) "

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

[8] Feitoza Costa, S.., " About temperature rise tests in IEC 61439-1 (LV) and IEC 62271-1(> 1kV HV) "

http://www.cognitor.com.br/IEC61439Table6.pdf

[9] Feitoza Costa, S.., " IEC 62271-307 – Extension of the validity of type tests to avoid tests repetition) "

https://www.cognitor.com.br/IEC62271307ENG.pdf

[10] Feitoza Costa, S.., " LV Circuit Breaker Power Dissipation : defines LV switchgear cost"

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

[11] Brochure Cigrè 602 "Tools for the simulation of the effects of the internal arc in transmission and distribution switchgear, TB602, Cigrè WG A3.24, 2014, ISBN : 978-2-85873-303-3

Annex A - PROPOSAL SENT BY SERGIO FEITOZA COSTA TO CIGRE STUDY COMMITTEES A3 and B3 FOR THE CREATION OF A WORKING GROUP

(State of the document when I received the last information before 2024 Paris Congress)

<table>
<tr><td>JWG [1]N° A3/B3_xx.</td><td colspan="2">Name of Convenor: Sergio Feitoza Costa (Brazil)
E-mail address: sergiofeitozacosta@gmail.com</td></tr>
<tr><td colspan="2">Strategic Directions #[2]: 1, 2, 3</td><td>Sustainable Development Goal #[3]: 9 - 12</td></tr>
<tr><td colspan="3">The WG applies to distribution networks: ☒ Yes / ☐ No</td></tr>
<tr><td colspan="3">Potential Benefit of WG work #[4] : 1, 2, 3, 4</td></tr>
<tr><td colspan="3">Title of the Group: VERIFICATION OF TEMPERATURE RISE LIMITS FOR T&D EQUIPMENT > 1 KV. IS IT POSSIBLE TO INCREASE THE VALUES TO SAVE MATERIALS ?</td></tr>
<tr><td colspan="3">Scope, deliverables and proposed time schedule of the WG:

Background:

Temperature rise test and temperature limits within product standards define equipment design and weights of product conductors. With the available experience and simulation capabilities today, these limits need to be verified to be able to establish new limits to enable less material to mitigate climate change.

Scope:

The objective of the WG work is to assess if the temperature rise limits used in IEC and IEEE standards could be increased and by how much. The steps would be:

• Raise the history that led to the limits used today within IEC and IEEE (consultations to experts and documentation). Clarify the duration of useful life they were associated with.
• Survey the R&D activities that have been carried out recently and that can bring evidence to propose raising the current limits (questionnaire & consultation with experts of IEC, IEEE, etc...)
• Survey of the existence or not of systematic problems with aspects of temperature rise. Focus in switchgear and T&D above 1 kV equipment. If there are few problems possibly limits can be increased (questionnaire)
• Make a proposal for limit values for “Synthetic OG” beside “OG” and “NOG” as oxidation is favoured by high humidity, high temperatures and presence of catalysts and presence of impurities or pollutants that can act as catalysts.
• Make a proposal for IEC and IEEE modificatives.
• To write a brochure including the conclusions of the work. In the results, to indicate the positive and negative impacts of increasing the temperature rise limits by 10K or 15K or 20K or more.

Relevant literature:
A3 - Brochure Cigrè 602 (2014) - Tools for simulation of the internal arc effects in HV and MV switchgear</td></tr>
</table>

A3 – Brochure Cigrè 830 (2021) - Application and Benchmark of Multiphysics Simulation Tools for Temperature Rise Calculations B3 – Brochure Cigrè 740 - Contemporary design of low-cost substations in developing countries IEC TR 60943 - 1998 - Guidance concerning the permissible temperature rise for parts of electrical equipment, in particular for terminals. **Deliverables:** ☒ Technical Brochure and Executive Summary in Electra ☒ Electra Report ☒ Future Connections ☐ CSE ☒ Tutorial ☒ Webinar **Time Schedule**: start: 04 / 2024 **Final Report**: Late 2026
Approval by Technical Council Chairman: **Date**:

Notes: [1] Working Group (WG) or Joint WG (JWG), [2] See attached Table 1, [3]See attached Table 2 and CIGRE reference Paper: Sustainability – at the heart of CIGRE's work. [4] See attached Table 3

Table 1: Strategic directions of the Technical Council

1	The electrical power system of the future reinforcing the End-to-End nature of CIGRE: respond to speed of changes in the industry by preparing and disseminating state-of-the-art technological advances
2	Making the best use of the existing systems
3	Focus on the environment and sustainability (in case the WG shows a direct contribution to at least one SDG)
4	Preparation of material readable for non-technical audience

Table 2: Environmental requirements and sustainable development goals

	CIGRE selected the 7 SDGs that are the most relevant to CIGRE. In case the WG work refers to other SDGs or do not address any specific SDG, it will be quoted 0.
0	Other SDGs or not applied

7	**SDG 7: Affordable and clean energy** Increase share of renewable energy; e.g. expand infrastructure for supplying sustainable energy services; ensure universal access to affordable, reliable, and modern energy services; energy efficiency; facilitate access to clean energy research and technology
9	**SDG 9: Industry, innovation and infrastructure** Facilitate sustainable infrastructure development; facilitate technological and technical support
11	**SDG 11: Sustainable cities and communities** Increase attention on sustainable and resilient buildings utilizing local (raw) materials, power for electric vehicles, strengthening long-line transmission and distribution systems to import necessary power to cities, developing micro-grids to reinforce the sustainable nature of cities; protect and safeguard the world's cultural and natural heritage; reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and waste management
12	**SDG 12: Responsible consumption and production** E.g. Promote public procurement practices that are sustainable; address reducing use of SF6 and promote alternatives, encourage companies to adopt sustainable practices and to integrate sustainability information into their reporting cycle, address inefficient fossil-fuel subsidies that encourage wasteful consumption
13	**SDG 13: Climate action** E.g. Increase share of renewable or other CO_2-free energy; energy efficiency; expand infrastructure for supplying sustainable energy; strengthen resilience and adaptive capacity to climate-related hazards and natural disasters; integrate climate change measures into national policies, strategies and planning; improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning
14	**SDG 14: Life below water** E.g. Effects of offshore windfarms; effects of submarine cables on sea-life
15	**SDG 15: Life on land** E.g. Attention for vegetation management; bird collisions; integration of substations and lines into the landscape

Table 3: Potential benefit of work

1	Commercial, business, social and economic benefits for industry or the community can be identified as a direct result of this work
2	Existing or future high interest in the work from a wide range of stakeholders
3	Work is likely to contribute to new or revised industry standards or with other long-term interest for the Electric Power Industry
4	State-of-the-art or innovative solutions or new technical directions
5	Guide or survey related to existing techniques; or an update on past work or previous Technical Brochures
6	Work likely to contribute to improved safety.

ANNEX B – PROPOSAL SENT TO CIGRE FOR THE CREATION OF NEW WORK ABOUT DISTANCES BETWEEN CABLES AND WINDOWS

Before checking the proposal check this video and article

Article: https://www.cognitor.com.br/FusesInTheWindows.pdf
Video: https://www.youtube.com/watch?v=dra1zBg9OuE

Portuguese version formally sent to the Brazilian National Standardization Committee

ARTIGO EM PORTUGUES https://www.cognitor.com.br/FusiveisPerigososNasJanelas.pdf

Video: Video: https://www.youtube.com/watch?v=dra1zBg9OuE

CIGRE Study Committee B2 (???) A2 (???) B3 (???) A3 (???)

PROPOSAL FOR THE CREATION OF A NEW WORKING GROUP

By Sergio Feitoza Costa

JWG [1]N° A3/B3_xx.	**Name of Convenor: _____** **E-mail address**: sergiofeitozacosta@gmail.com
Strategic Directions #[2]: ~~1, 2, 3~~	**Sustainable Development Goal #[3]: ~~9 - 12~~**
The WG applies to distribution networks: ☒ Yes / ☐ No	
Potential Benefit of WG work #[4] : ~~1, 2, 3, 4~~	
Title of the Group: **"DANGEROUS DISTANCES BETWEEN 13,8KV CABLES / TRANSFORMERS TO BUILDING FACADES AND LAYPEOPLE WINDOWS in URBAN CIRCUITS"**	

Scope, deliverables, and proposed time schedule of the WG:

Background:

Having a 13.8 kV cable right in front of and close to the window where laypeople are present is very dangerous but not properly addressed in IEC standards. The 3 danger factors to consider from design to construction of urban transmission lines near buildings are the (a) MAGNETIC and ELECTRIC FIELDS limits to attend ICNIRP Guidelines, (b) DIELECTRIC DISTANCES from cables or busbars (like in IEC 61936) and - the more dangerous - (c) EXPLOSION OF DISTRIBUTION TRANSFOMERS and EXPULSION FUSES that can kill people (distances like 7,6m in IEC61936 but less than 2m in the real life).

In developing countries, urban overhead lines near buildings are typical rather than an exception. The dangers of transformer explosions and expulsion fuses are demonstrated in the video and article below. Dangers of internal arc overpressures so well addressed by IEC62271-200 have simply not been considered for distribution transformers in the streets. About the dielectric distances, standards do not consider that lay people, especially children, being close to the cable could extend objects towards it. Seems that the small distances practiced for buildings were focused only in attending the limits of magnetic and electric fields.

The Brazilian standard ABNT NBR 15688, "Aerial electrical energy distribution networks with bare conductors", serves as an illustration. It stipulates that 13.8kV cables must be kept at least 1.5 meters away from facades, while IEC 61936-1 specifies a minimum of 7.5 meters within a substation, for equipment with oil. Using such a small distance is taking the risk of killing. Cigré has the neutrality to study the subject and propose the improvement of these standards. A barrier for changes is that the citizen at the window does not participate in the preparation of standards drawn up by almost 100% of experts from power utilities, not interested in changes.

Today, in Brazil, if you want to remove the transformer next to the window, you need to file a lawsuit because power utilities states that are following the technical standard.

Scope:

The objective of the WG work is to assess the existing standards and to propose suggestions to IEC, considering that that most national standards follow the same rules. The steps would be:

- Raise the history that led to the minimum distances that are used today within IEC and IEEE (consultations to experts and documentation). Identify similarities between the IEC61936 guide for values of outdoor transformers clearances.
- Survey the practices adopted all over the World that can bring evidence to propose raising the minimum distances (questionnaire & consultation with experts of IEC, IEEE, etc...)
- Survey of the existence or not of systematic problems like accidents with an association to the minimum distances practiced.
- Make a proposal for IEC and IEEE of new values of minimum distances from the aerial cables, distribution transformers and fuses, to building facades.
- As far as possible, make an economic comparison between the resources necessary to change distances in new installations and the use of underground networks. Indicate strategies for mitigating existing hazards within a period of, say, 10 years.
- To write a brochure including the conclusions of the work. In the results, to indicate the positive and negative impacts of increasing the minimum distances.

Relevant literature:

Article by Eng. Sergio Feitoza Costa “About Placing A Hv Transformer + Fuses That Could Explode - In Front Of A Window Where Children Live? “ : https://lnkd.in/dFnMt3SP

Video with the same title of the article by Eng. Sergio Feitoza Costa: https://lnkd.in/dvrUPAXt

A3 - Brochure Cigrè 602 (2014) - Tools for simulation of the internal arc effects in HV and MV switchgear
B3 – Brochure Cigrè 740 - Contemporary design of low-cost substations in developing countries.

Deliverables:

☒ Technical Brochure and Executive Summary in Electra

☒ Electra Report

☒ Future Connections

☐ CSE

☒ Tutorial

☒ Webinar

Time Schedule: start: 09 / 2024 **Final Report**: Late 2026

Approval by Technical Council Chairman:
Date:

Notes: [1] Working Group (WG) or Joint WG (JWG), [2] See attached Table 1, [3]See attached Table 2 and CIGRE reference Paper: Sustainability – at the heart of CIGRE's work. [4] See attached Table 3

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2	Making the best use of the existing systems
3	Focus on the environment and sustainability and risks to laypeople (in case the WG shows a direct contribution to at least one SDG)
4	Preparation of material readable for non-technical audience

Table 2: Environmental requirements and sustainable development goals

	CIGRE selected the 7 SDGs that are the most relevant to CIGRE. In case the WG work refers to other SDGs or do not address any specific SDG, it will be quoted 0.
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11	**SDG 11: Sustainable cities and communities** Increase attention on sustainable and resilient buildings utilizing local (raw) materials, power for electric vehicles, strengthening long-line transmission and distribution systems to import necessary power to cities, developing micro-grids to reinforce the sustainable nature of cities; protect and safeguard the world's cultural and natural heritage; reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and waste management

12	**SDG 12: Responsible consumption and production** E.g. Promote public procurement practices that are sustainable; address reducing use of SF6 and promote alternatives, encourage companies to adopt sustainable practices and to integrate sustainability information into their reporting cycle, address inefficient fossil-fuel subsidies that encourage wasteful consumption
13	**SDG 13: Climate action** E.g. Increase share of renewable or other CO_2-free energy; energy efficiency; expand infrastructure for supplying sustainable energy; strengthen resilience and adaptive capacity to climate-related hazards and natural disasters; integrate climate change measures into national policies, strategies and planning; improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning
14	**SDG 14: Life below water** E.g. Effects of offshore windfarms; effects of submarine cables on sea-life
15	**SDG 15: Life on land** E.g. Attention for vegetation management; bird collisions; integration of substations and lines into the landscape

Table 3: Potential benefit of work

1	Commercial, business, social and economic benefits for industry or the community can be identified as a direct result of this work
2	Existing or future high interest in the work from a wide range of stakeholders
3	Work is likely to contribute to new or revised industry standards or with other long-term interest for the Electric Power Industry
4	State-of-the-art or innovative solutions or new technical directions
5	Guide or survey related to existing techniques; or an update on past work or previous Technical Brochures
6	Work likely to contribute to improved safety.

ANNEX C - GUIDELINES FOR THE USE OF THE "ENVIRONMENTAL EFFICIENCY CERTIFICATE OF ELECTRIC PRODUCTS"

Link for the complete article

https://www.cognitor.com.br/demo1certificate.pdf

Read first the initial page of this article with a proposal for a technical standard

kG /MVA : an indicator of Environmental Efficiency of Electric Products

PRIZE for PATENTS & INNOVATIONS. in power T&D products.

for saving Planet resources giving good ESG examples.

By Sergio Feitoza Costa

ABSTRACT

Imagine if **ABB, Schneider, Hitachi, Siemens, Eaton, and other global titans of the electrical industry banded together to improve their image as guardians of the environment**. They would hold a competition to disseminate ideas and concepts that could cut the amount of materials used in the electrical sector and boost energy efficiency by lowering power losses. The goal would be to develop more effective substitutes for the designs that have been commercialized globally for decades, since the time when taking care of the environment and saving the Earth's resources was not a priority. The terms "Temperature Rise Limits and IEC / IEEE technical standards" are the key, but it is missing an efficiency indicator like the kg/MVA transmitted of products to demonstrate that a design is better than others. It is unbelievable that these standards, at no time, encourage or mention that using fewer materials is good for the Planet. **In this article**, we present a suggestion for a technical standard. The central idea on how to organize the "PRIZE" is presented. We hope that this text will draw the attention of the senior management of these companies to the need to do the right thing in this difficult moment, as they did competently in the past. It would be great to see this text arriving to funds to support sustainable development and climate action.

Link for the article http://www.cognitor.com.br/demo1certificate.pdf

(follow several pages of the article in the link above)

ANNEX: BASE TEXT PREPARED BY SERGIO FEITOZA COSTA IN FORMAT OF ISO / IEC for

GUIDE (Edition 1.0):

Guidelines for the use of the "ENVIRONMENTAL EFFICIENCY CERTIFICATE OF ELECTRIC PRODUCTS"

CONTENTS

FOREWORD

This "Environmental Efficiency Certificate for Electrical Products" aims to induce the electric industry to produce products that goes beyond the quality assured by prescribed type tests . The focus is on highlighting designs and construction actions on electrical power products that lead to lower weight per transmitted power (KG/MVA). This is directly associated with saving Earth materials and climate change. The indicator (KG/MVA) aims to characterize higher efficiency and lower use of materials. It can be used to improve the environmental image.

To obtain the Certificate, it is necessary to pass design verifications that are specified to meet specific requirements and tests. To evaluate these characteristics, real tests, calculations, and simulations may be used.

Laboratory type testing, as specified in product standards, is the most used way to verify if a certain product attends the specifications. However, it is necessary to recognize that tests are expensive and a barrier for new developments. Nowadays there are lower cost alternatives of design verification like testing simulations.

Using the design parameters shown in the tables of IEC TR 62271-307 for Extension of Validity of Test Reports makes it easier to verify the higher efficiency of designs. Testing simulation techniques can predict results of most types of tests. They enable us to compare – at a low cost - different designs to see which one is more efficient (lower kG/MVA).

Let's use as an example a simple reference electrical busbar made of copper busbar 1x100x10 mm. The connection between bars is bare. Suppose you do a testing simulation increasing the value of electric current up to the level that the temperature

rise of the hot spot is equal to the temperature rise limit prescribed in the technical standard (60K for bare connections). Then you will now do the same simulation for another electrical busbar equal but having 2x100x5mm busbars. The weight of both is the same but the second simulation will show that it is more to pass current than the first test , reaching the same 60K. This means that the second design has the same weight but a lower kG/MVA than the first one. So, it is more efficient to save materials.

The main concern related to the use of testing simulations instead of real type tests is to be sure that their results are equal to the results of a real laboratory, within an acceptable tolerance. This Guide exemplifies tolerances values and give guidelines to validate the methods. Temperature rise tests are the main test to define the weight of equipment busbars. The validation of the simulation method is simple because you just compare the temperature rise measured in the test with the simulation results.

The key aspect for analyzing if a certain design is more efficient than others, is to define an indicator reference values for the comparisons. To define initial reference values, worldwide queries can be made, initially only, for switchgear , switchboards, and busways (IEC 62271 and IEC 61439 series). You need only to know the weight of the equipment and the transmitted power of a product in the limit of passing in the test. So, you have the kg/MVA of that design.

This Guide presents some initial reference values of KG / MVA for typical commercial products.

GUIDELINES FOR THE IMPLEMENTATION OF THE "ENVIRONMENTAL EFFICIENCY CERTIFICATE OF ELECTRIC PRODUCTS

1 Scope

This Guide presents guidelines for the systematization of the use of the environmental efficiency Certificate of electric products. The use of this "Certificate" is an action to motivate the electric industry to design and manufacture more efficient electric power products with lower kG/MVA. The concept is that , as the Certificate becomes known in the world market, companies, especially the ones that need to take care of the environmental image, will prefer to buy products with use less materials that is to have a lower KG / MVA.

The Certificate attests that the project was made to meet the requirements of the tests prescribed in the product standard but, much beyond this, was designed to a lower use of copper, aluminum, insulating supports, materials etc. This is a measurable objective using an indicator like the weight per transmitted power (KG/MVA) of the product .

To facilitate the understanding let's consider switchgear products according to IEC61439 or IEC62271 series. A simple example is that with a single copper bar 100x10 mm you may transmit a certain value of electric current attending a specified temperature rise limit. However, if you use 2x100x5mm (same weight) , for the same temperature rise value, you can transmit quite more current. Higher current means higher MVA and so the indicator KG/MVA is lower in the second case.

A key aspect is that this kind of verification, as in the example above, can be done using real laboratory tests or, faster and cheaper, using validated test simulations. By this reason this Guide give orientation on how to validate test simulations.

The main aspect behind the Certificate is that the product has passed all relevant type tests. The temperature rise test is of particular importance because the weight of busbar conductors is directly associated with the temperature rise limits specified in technical standards. Equipment is composed by conductors; busbar supports and enclosures. Usually, the biggest influence in the kG/MVA of a product is the weight of the busbars.

The Certificate shall be issued by third parties under the concepts in these Guidelines. The verifications and results that lead to the kG/MVA indicator shall be transparent, auditable, and reproducible. The design parameters presented in the tables of IEC TR 62271-307 shall be used.

The data to support the Certificate can be obtained from test reports or from validated testing simulations, considering the design parameters of the

tables and concepts IEC TR 62271-307. This IEC document allows, if certain rules are met, to extend the validity of test reports of tests carried out on a certain product representative of a family, to demonstrates that if the tested one passed the tests, other similar non-tested ones would also pass. It is based on sound technical principles.

The extension of the validity of test reports seeks to avoid unnecessary repetition of tests of IEC 62271-200/201 standards. It can be used to extend type tests performed on one sample with a defined set of ratings for another product of the same family with a different set of ratings or different arrangements.

A relevant aspect in IEC62271-307 is the explicit mention to the use of testing simulations used in a comparative sense. If the testing simulations done in the tested equipment give the same results as the real test, they can predict what will be the performance of other non-tested samples.

In other words, suppose you test a product and simulate that test getting the same results. Suppose you now have another design of the same nature as the tested one, but with some differences. If you simulate the tests of the new equipment, using the same tool and a qualified method, there is no reason to question whether the new simulation represents what would happen in a real test.

It is expected that, after some time of application of this Guide, the world values of the kG/MVA indicator become well known, unlike today. The consequence will be creating a higher step of design efficiencies with less use of materials and lower weight.

The verification reports issued by the qualified certifiers shall indicate in clear words that the equipment has passed the tests and demonstrate KG/MVA indicators. It is particularly relevant to the performance in temperature rise tests (weight of conductors), short circuit tests (higher electrodynamic forces means higher amount and weight of supports) and internal arc tests (weight of enclosures).

Some verifications are possible only when certain specific measurements are presented in the laboratory test report. So, the test reports shall include measurements and photographic registers that make the test to be reproducible

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

2 Normative references

The following referenced documents may be used for the application of this Guide, where relevant. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

b) IEC TR 62271-307:2015 : 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

c) IEC TR 60943: Guidance concerning the permissible temperature rise for parts of electrical equipment, in particular for terminals.

d) IEC TR 60890: A Method of Temperature-rise Verification Assessment by Extrapolation for Partially Type-Tested Assemblies (PTTA) of Low-Voltage Switchgear and Controlgear Assemblies by calculation.

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

f) IEC 60865-1: Short-circuit currents – calculation of effects – Part 1: Definitions and calculation

g) IEC 60865-2: Short-circuit currents – calculation of effects – Part 2: Examples of calculation

h) IEC 60112: Method for the determination of the proof and the comparative tracking indices of solid insulating materials

i) IEC 60071 1: 2010 Insulation co-ordination - Part 1: Definitions, principles and rules

j) Brochure CIGRE 602 / 2014 Tools for the Simulation of The Effects of the Internal Arc in T&D Switchgear

k) Brochure CIGRE 740 (2018) Contemporary Solutions for Low-Cost Substations.

l) Brochure CIGRE 830 (2021):Application and Benchmark of Multiphysics Simulation Tools for Temperature Rise Calculations

3 Definitions

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

3.1 – kG/MVA (weight divided by transmitted power) of an electric product

The aim of the Certificate is to attest that the product was made to meet the requirements of the tests prescribed in the product standard but, much beyond this, was designed with the minimum necessary use of copper, aluminum, insulating supports, materials etc. To measure this objective the indicator to be used is the weight per transmitted power (KG/MVA) . For example, a single copper bar 100x10 mm can transmit 20% less current than using 2x100x5mm (same weight) , for the same

temperature rise. So, the indicator KG/MVA is lower in the second case. Less materials were used, and higher efficiency was obtained. This is better for the Planet resources.

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

A calculation method used to predict, within a certain specified tolerance, the results which would occur in a laboratory test as specified in the relevant product standard. Here are typical values of acceptable tolerances of the results to be obtained in the simulations if compared to the real laboratory test results:

Table 1

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 value and integral of the pressure curve)	5% to 10%
Short time withstand current, and peak withstand current tests	Electrodynamical forces and mechanical stresses	5% to 15%
Other applicable tests	The ones listed in IEC 62271-307.	(*)

(*): Values of tolerance to be defined.

3.3 - Product publication

Publication covering a specific product or group of related products

34 - Reproducibility of a simulation or calculation method

The capability 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.

3.5 - Validation of a simulation or calculation method comparing to laboratory test results

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

3.6 - Minimum input data to be registered in a temperature rise laboratory test report.

Temperature rise is the main parameter which defines the kG/MVA of a product. 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 shown in the relevant product standard. IEC TR 60943 and IEC 60890 explain the concepts involved.

The data affecting the results are the ones explained in the relevant table of IEC 62271-307 . The main ones 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 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 the laboratory test report. The values of the data mentioned above shall be clearly registered in the test report trough drawings and photos,

3.7 - Minimum input data to be registered in 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 parameter to predict a good or bad test result. The data affecting the test, and the simulations results are the ones explained in the relevant table of IEC 62271-307 . They are explained in the reference Brochure CIGRE 602 / 2014. The main ones 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,

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

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

The data affecting the test, and the simulations results are the ones explained in the relevant table of IEC 62271-307 . They are explained in the references IEC 61117, IEC 60865-1 and IEC 60865-2. The main ones 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 the laboratory test report. The values of the data mentioned above shall be clearly registered in the test report trough drawings and photos,

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

4 Working procedures

4.1 General

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

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

4.2 Product publications

Committees developing product publications, involving subjects covered by this

Guide, shall incorporate this Guide into their own publication by reference. If necessary, they may specify, in their own publications, additional details relevant to their product area

5 QUALIFYING FOR CERTIFICATES

5.1 Steps of the assessment

The usual sequence to obtain the certificate is:

- Test a head of family product using the related product technical standard. Define the electric current (I) that will imply in reaching the permitted temperature rise limit in the hot spot. Register the total weight of the equipment The kG/MVA will be equal to the weight divided by 1.732 x I x rated voltage of the equipment. Simple like this.
- Search for a certification company able to analyze the data and to verify the correctness of the KG/MVA calculated values.
- This entity will issue the CERTIFICATE explaining the details transparently and making statements based on the values of kG/MVA currently practiced in the market.

The initial procedure is to collect data and test reports results of an already (approved) tested design. If testing simulations are used, they should use transparent and validated verifiable tools and methods.

The relevant design parameters to be considered in the tests or test simulations are the ones described in the relevant table of IEC TR 62271-307 . In addition to those parameters, data related to the weight of conductor materials, insulating materials and enclosures will be registered. The final objective is to calculate the indicator KG/MVA as defined in section 3.1.

The Certificate shall inform if the untested sample would be expected to be approved in the type tests and the KG/MVA indicator. The relevant data shall be presented in a single figure like in the example in Section 5.2.

5.2 An example of a typical assessment

Text to be prepared, based on data below.

Table 2 – Input data for the simulation of temperature rise test, internal arc tests and short time current peak withstand tests.

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

Table 3 – Temperature rise test and simulation results (K).

Point of the measurement	Test result (K)	Simulation result (K)
Connection at conductor # 1 (short circuit point)	47	42
Connection at the end of conductor # 3 (circuit breaker - low)	57	54
Connection at the end of conductor # 4 (circuit breaker-low)	64	66
Connection at the end of conductor # 5 (circuit breaker-high)	64	65
Connection at the end of conductor # 6 (circuit breaker-high)	52	53
Connection at end of conductor # 7 (top horizontal)	32	28
Enclosure door circuit breaker	5	

Fluid 50% height - cables compartment	not measured	13
Fluid 50% height - circuit breaker compartment	not measured	9
Fluid 50% height – bus-bars compartment	15	15

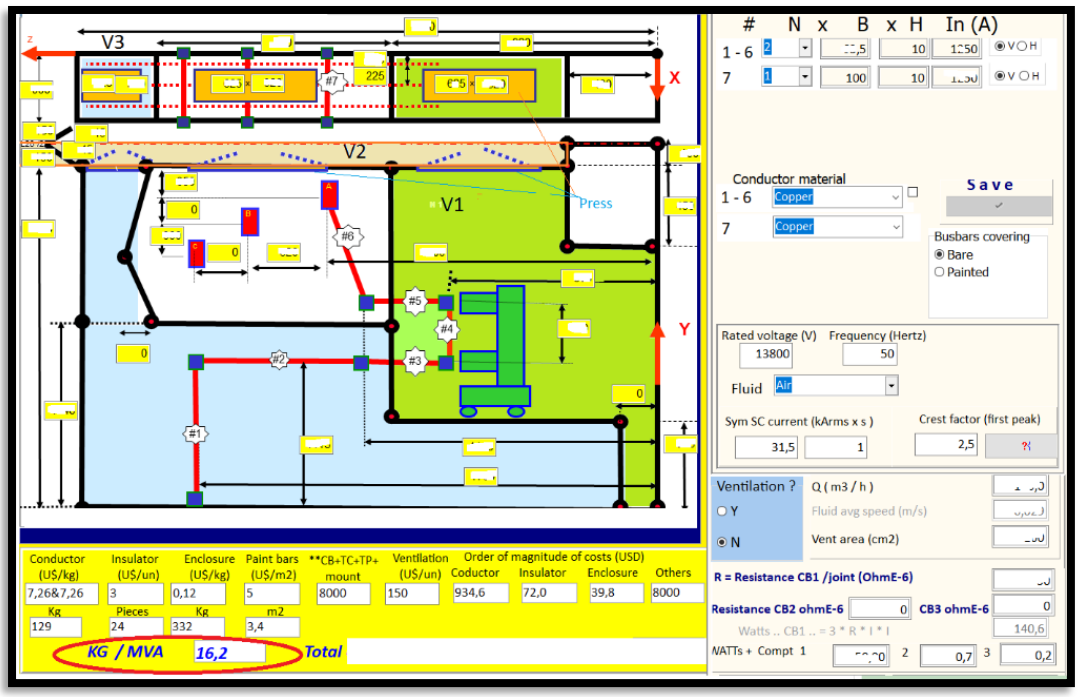
Table 4 – Internal arc test and simulation results (K).

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

Table 5 – Short-time withstand current, and peak withstand current test and simulation results

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

Figure 2 – Input data to be used in the assessment of designs according to the parameters in the Tables of IEC 62271-307. The numbers of the conductors are the same used in Tables 2 to 5



4 Recommended statements in IEC products standards.

IEC STANDARDS STATEMENT about SAVING MATERIALS (as was done with EMC in 1980s): Reduced use of copper, aluminum & insulators is beneficial for the environment. All product standards should add this clause: "PRODUCTS COVERED BY THIS STANDARD use significant amounts of copper, aluminum, insulators, and metals. Material savings are desirable for the Climate Change and Energy Transition initiatives. IEC promotes designs and methods that lower the kg/MVA" designs.

REFERENCES

LIKE THE LIST IN PAGE 17 OF THIS BOOK

END OF THE DRAFT STANDARD

ANNEX D – A TRAINING + DESIGN REVIEW + LECTURE (INCLUDING SWITCHGEARDESIGN) ABOUT SWITCHGEAR, SWITCHBOARDS, PANELS, BUSDUCTS OF IEC62271-200 / IEC62271-307, IEC61439

To watch the 7 videos posted in Sergio Feitoza Costa LinkedIn profile from Aust, 16 to October 11 -2024 click the links in next lines

Training on Electric Panels Design in 7 (free) video-classes

All Videos links from August,16 to October 11 – 2-24
TEMPERATURE RISE – Design concept & Tests. (IEC61439 + IEC 62271) .. https://youtu.be/jCEK2TxZ_AA
SHORT CIRCUIT ELECTRODYNAMIC FORCES: Concepts, IEC 61117, IEC TR 60865. https://youtu.be/kzEo1tlJkQM
INTERNAL ARC TESTS - IEC 62271-200 e 307 (MV), IEC TR 61641 (LV). https://youtu.be/56L-lxe7awI
MAGNETIC and ELECTRIC FIELDS and THEIR EFFECTS (Concepts and Mapping) https://youtu.be/nZ94fuTM2gY
OVERVOLTAGES & INSULATION COORDINATION https://youtu.be/Ueak7Et4UyU
ENCLOSURES FOR LV SWITCHGEAR: IEC 60890 + IEC 62208: https://youtu.be/2zWojzAJOXg
IEC STANDARDS for MV & LV SWITCHGEAR https://youtu.be/EcouAVUmwx8 and https://youtu.be/2KwgxcvjRoc

Design Review + Training + SwitchgearDesign: https://www.cognitor.com.br/proposal.pdf

LECTURE OCTOBER 2024

Tests, Specification, Efficient Design to Save Planet Materials & Technical Standards

October , 2024

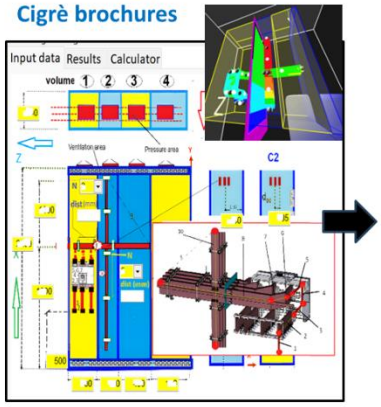
Presented by Sergio Feitoza Costa

- Design is better if it passes the tests, close to the limits and does not waste Planet's materials. Choose more efficient projects.
- Temperature rise test defines the cost of the product
- Only buy equipment verified by the IEC 62271 (high voltage) and IEC 61439 (low voltage) Standards
- IEC and IEEE technical standards shall evolve from focus (only) on severe tests to encourage efficiency + and less use of materials
- Main specifications, tests and approval criteria.
- NBR IEC 61439 texts difficult to understand (temperature rise test, limits and applicability of the “design rules”.)
- Extending the validity of reports avoids expensive tests. Nothing prevents use of IEC 62271-307 (medium voltage) in low voltage panels.

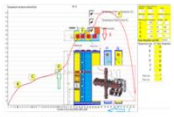
- A design is better if it passes the tests, close to the limits so as not to waste the planet's materials.
  - Old practices over dimensioning to pass the expensive tests 1st time **X** saving Planet´s materials
- How to develop more efficient projects+?
  - Test simulations cost less than 10% of laboratory tests. Go to lab only to do final type tests.

Testing simulations are the new fact !

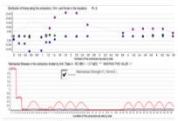
Cigrè brochures



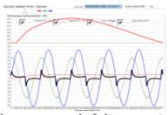
Temperature rise



Short circuit forces



Internal arc overpressures



Sergio: cortar duração do vídeo. Só o teste

- Temperature rise test defines design and costs. (close to limits = less materials)
- Most important design aspects

• Why only to buy panels verified according to IEC 62271 (high voltage) and IEC 61439 (low voltage) standards?

- The test report is the (minimum) guarantee that what was tested is what you are buying.
- Good identification of what was tested is necessary
- The report must say whether or not “approved in the test”

IEC and IEEE standards need to evolve to not focus solely on severe testing.

- There are no statements to encourage greater efficiency & less use of materials (should have)
- Opportunity for large users who need to maintain a good environmental image: take into account kg/MVA indicator (read article)

Main Specifications, testes and approval criteria

- Short circuit tests (breaking and forces)
- Temperature rise test
- Dielectric tests
- Internal arc tests (in LV should be type test like it is in HV standard)

IEC 61439 texts that are difficult to understand (temperature rise test method, limits to define approval and applicability of "design rules".)

- IEC 60439 x IEC 61439 Standard (article)
- Temperature rise test and limits (text previously clear and rational in IEC60439 became difficult to understand in IEC61439. Test method is a barrier to small manufacturers)
- Applicability of poorly written design rules in IEC61439
- Poor text of the IEC standard is translated in full but could be improved in the Brazilian (and other) national standards.

Extending the validity of test reports prevents expensive testing. Nothing prevents to use IEC 62271-307 (medium voltage) for low voltage panels.

Article

- The good idea of the "design rules" has been distorted by the bad text of last revision of IEC61439. It was valid for temperature rise and short circuit and now it is understood that it is only for short circuit.
- IEC 62271-307 (15X higher energy products) uses the concept of "design rules" for ALL tests (a transparent table for each)
- Technical standards for products such as panels are usually not mandatory (compulsory) .
- https://www.gov.br/inmetro/pt-br/acesso-a-informacao/perguntas-frequentes/avaliacao-da-conformidade/como-saber-se-meu-produto-podedeve-ser-certificado
- Use it whoever wants. Sale contract prevails or is law? Where is written ?.
- MV and LV panels differ only in the voltage. Materials, functionalities and tests are the same (but well written in high voltage standard)
- Using IEC 62271-307 to extend validity is a common sense, well-founded option and leads to lower cost products by reducing repetitions of tests.

Thank you very much for the attention

COGNITOR

References and links for the articles

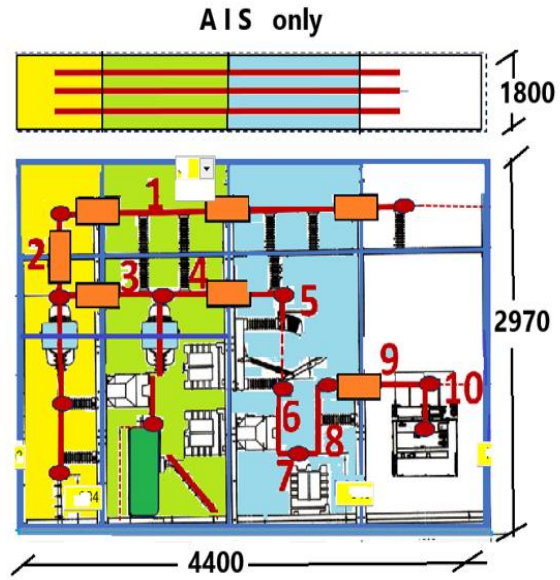
[1] CIGRÈ BROCHURE 602 (2014) Tools for Simulation of The Effects of the Internal Arc in T&D Switchgear, ... (*)
[2] CIGRÈ BROCHURE 740 (2018) Contemporary design of low-cost substations in developing countries. ..... (*)
[3] CIGRÈ BROCHURE 830 (2021) – "SIMULATIONS FOR TEMPERATURE RISE CALCULATION". ..... (*)
[4] **IEC TR 62271-307** :2015 - High-voltage switchgear and controlgear - Part 307: Guidance for the extension of validity of type tests of AC metal and solid-insulation enclosed .... for rated voltages > 1 kV .. <= 52 kV .....(*)
[5] **Article about** IEC62271-307 (2015) https://www.cognitor.com.br/IEC62271307ENG.pdf .....(**)
[6] BOOK free Reading - Training "SWITCHGEAR, BUSWAYS & OTHER SUBSTATIONS T&D Equipment https://www.cognitor.com.br/Book_SE_SW_2013_ENG.pdf .....(**)
[7] **IEC TR 60943** :1998 - Guidance concerning the permissible temperature rise for parts of electrical equipment, for terminals. Issued by IEC Technical Committee TC 32 when Sergio was chair.
[8] **Article:** "TEMPERATURE RISE LIMITS OF IEC 61439-1 : unclear values distort the LV switchgear market.
http://www.cognitor.com.br/IEC614391Table6.pdf e também https://www.cognitor.com.br/IEC61439Table6.pdf ...(**)
[9] **Article:** How to use IEC 62271-307 (MV) to extend the validity of test reports for LV switchgear ?:
https://www.cognitor.com.br/mudarIEC61439.pdf ...(**)
[10] **Article:** ENVIRONMENTAL EFFICIENCY CERTIFICATE OF ELECTRICAL PRODUCTS (KG/MVA): A PRIZE AND A TECHNICAL STANDARD http://www.cognitor.com.br/demo1certificate.pdf ...(**)
[11] **REPORT** 150/2024: Training, Installation & Validation of Testing Simulations of high-power tests with Software SwitchgearDesign ... https://www.cognitor.com.br/TR_150_ENG_ValidationSwitchgearDesignSWD.pdf ...(**)
[12] BOOK free reading "TEMPERATURE RISE LIMITS IN SWITCHGEAR of IEC STANDARDS: an overlooked key to save Planet's resources (with an idea to reduce size of AIS MV switchgear, a training and a lecture)" https://www.cognitor.com.br/TemperatureRiseLimits.pdf ...(**)
[13] **Other articles** https://www.cognitor.com.br/Downloads1.html

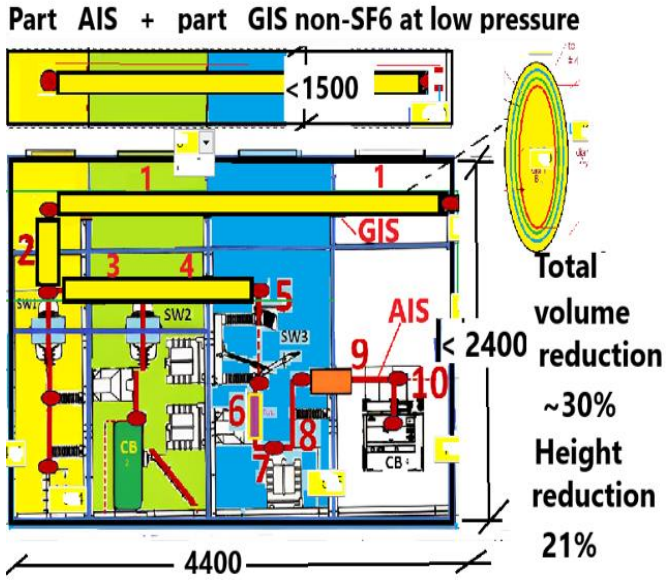
(*) Sérgio is coauthor .... (**) Sergio Feitoza Costa is author

- C.V: https://www.cognitor.com.br/HelpedToDo.pdf e https://www.cognitor.com.br/Curriculum.html
- "Non – technical " production of books and songs https://www.cognitor.com.br/MusicSergioFeitoza.html + www.cognitor.com.br

ANNEX E – AN IDEA TO REDUCE THE SIZE OF AIS SWITCHGEAR UP TO 38KV USING A MIXED AIS + TRIAXIAL GIS SOLUTION WITH NON-SF6 GASSES.

Proof of concept using SwitchgearDesign software models for 38 kV switchgear





	AIS only	AIS + GiS Non-SF6 Low Press.
Total volume	100%	<70%
Height	100%	<19%
Depth	100%	<17%

About the Author

Sergio Feitoza Costa is an inventor, composer, musician, fiction books writer and electrical engineer, not necessarily in this order.

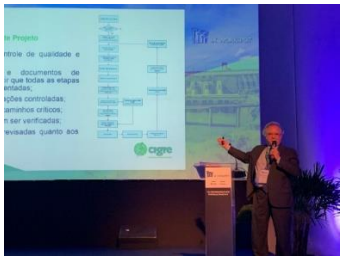
Alongside a successful career of over 45+ years in electrical engineering R&D has parallel activities with music production and fiction books writing.

There are free books, C.V., and other materials in http://www.cognitor.com.br

Presentation Manilla -Philipines - Cigrè

Presentation Manilla -Philipines - Cigrè

Presentation in Iguassu Falls



Show in Rio de Janeiro - Brazi

ISBN: 978-65-01-18637-5

Training in Guangzhou China

Training in Guangzhou China

Training in Angola – Cambambe Power

Training in Bogotá - Colombia