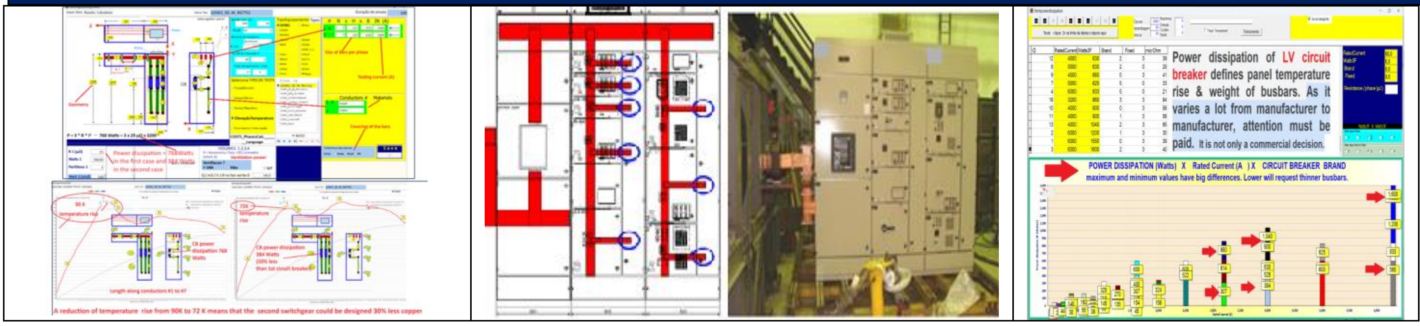
Consultancy, R&D and Training Ltd

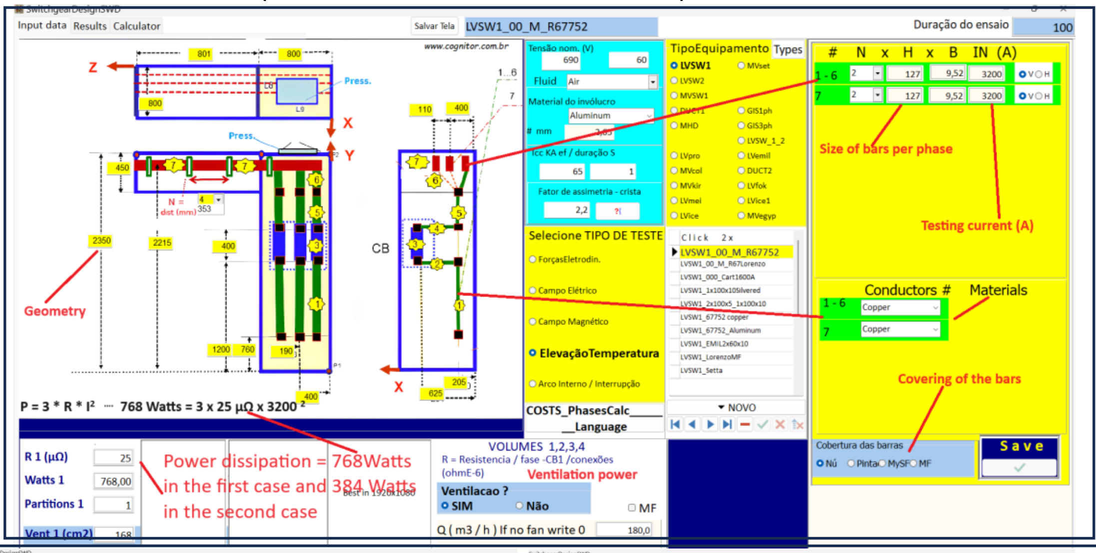
LV CIRCUIT BREAKERS: the way to a lower-cost LV switchgear is to select a CB brand with lower POWER DISSIPATION.

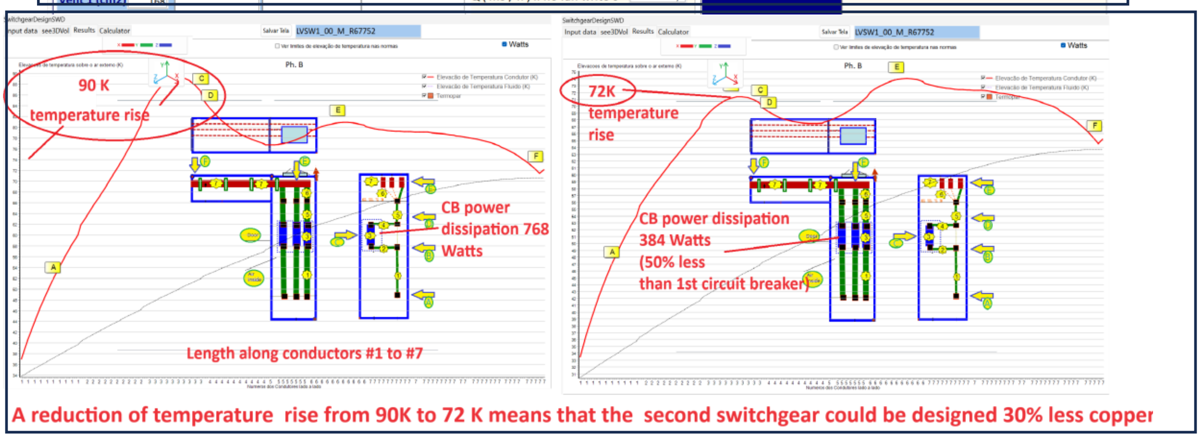


Contact: e-mail: sergiofeitozacosta@gmail.com Site: www.cognitor.com.br Article: https://www.cognitor.com.br/LVcircuitBreakerDevelopment.pdf

1. WHY A LOWER POWER DISSIPATION OF A LV CIRCUIT-BREAKER IS BETTER ?

It is simple to show that CB resistances determine the hottest locations observed during temperature rise tests. Doing this with real tests is expensive and takes time. However, doing this with testing simulations is easy, safe, and fast. Check this example with two circuit breakers where the power dissipation of the second one is 50% lower than first one (384 Watts instead of 768 Watts).





The hot-spots are typically busbar connections to circuit-breakers, switches, and fuses. The resistance of the CB as seen from the terminals, is the more important factor in defining the cost of producing a panel with CBs. The reason is that more resistance R means more CB power dissipation ($P = 3 * R * I^2$) and higher temperature rises inside the enclosures. So, if you can choose between approved circuit-breakers from several different brands, the one with the lowest power dissipation would be the better by causing lower temperature rises. Simple like this. That's why the choice of circuit breaker is not only a commercial issue. The other important aspect is the temperature rise limit of circuit breaker terminals.

For those who want to understand, start by reading the document IEC TR 60943 [Ref. 1]. The 1st edition was published in 1989 when I was chair of IEC TC32. (Fuses). Other useful publications are the Cigrè Brochure 830 (Ref. [2] – temperature rise simulations) and Cigrè Brochure 740 (Ref. [3]- low-cost substations.). I am also coauthor of these brochures.

A complete document explaining about temperature rise problems is my article of Ref. [4] named "Table 6 of IEC 61439-1: What temperature rise limits to use when approving or certifying low voltage switchgear? Here the reader can understand the impact of power dissipation, and of the temperature rise limits used in the temperature rise tests. I show also the problems caused by IEC 61439-1 temperature rise test method and the badly written Table 6 of IEC 61439-1. IEC top management should investigate this matter as it is a source of commercial problems. Imagine the situation of a manufacturer who lost a bid because they designed a LV switchgear to a 75K temperature rise limit (correct but uses more copper), while another one could offer a lower price because (wrongly) interpreted the limit as 105K.

I proposed to Cigrè to form a working group to study if it is possible to increase some values of temperature rise limits applicable to connections and contacts. For connections, around 10-15K, means using much less copper and aluminum. Check the term of reference at the end.

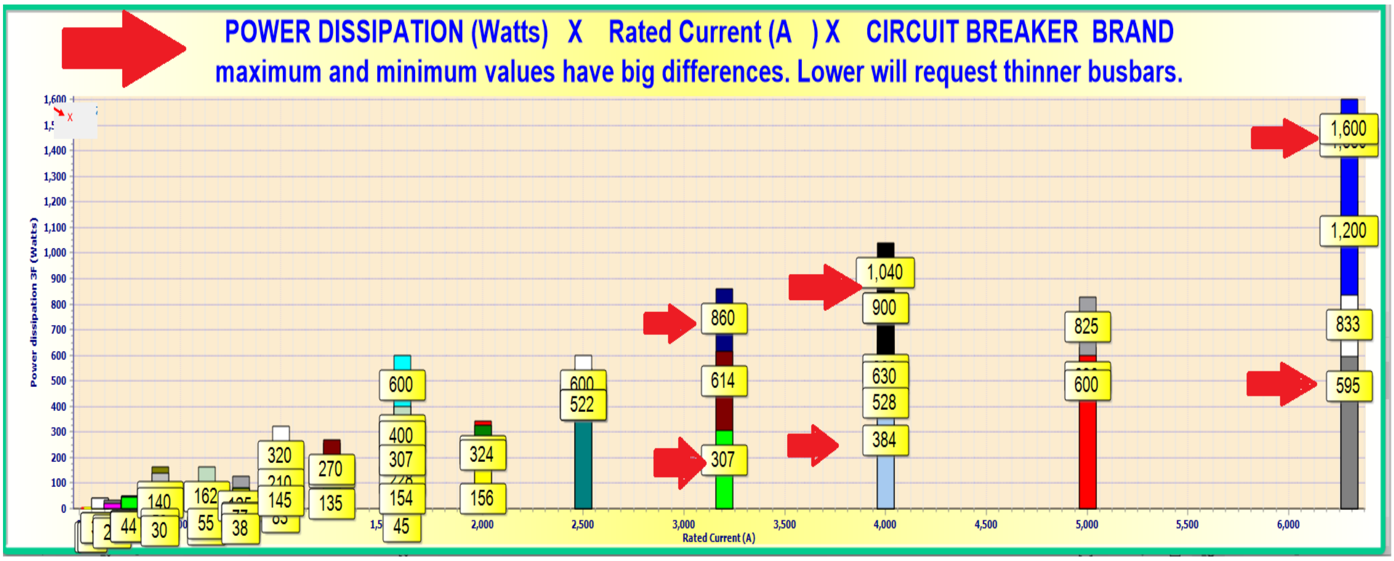
The fact is that, if a manufacturer wants to make a lower cost design should look carefully to the aspect of selecting the circuit breakers. If you manage to design an equipment that is slightly below the limits of temperature rise permitted in the technical standard, you get the most competitive project. Check in Table 1 comparative values of the bus bar needed to be approved in the test. They depend on the standard temperature rise limits and CBs power dissipation.

Table 1 – Cross-section of main busbar needed to be approved in temperature rise test.
Versus temperature rise lit X power dissipation – Current 2500 A – dimensions mm

Temperature rise ΔT (K)	Circuit breaker power dissipation $3\phi = 3 \times R \times I^2$ (Watts)			natural ventilation net area (cm2)
	150W	**300W**	**600W**	
60K (bare)	**1 x 160x10** (50%)	**2 x 160x10** (100%)	**2 x 250x10** (156%)	180 cm2 bottom 180 cm2 top
75K (silvered / recommended)	**2 x 120x10** (75%)	**2 x 140x10** (87%)	**2 x 160x10** (100% peso)	180 cm2 bottom 180 cm2 top
85K: if considered only the circuit breaker	**1 x 150x10** (47%)	**2 x 80x10** (50%)	**2 x 120 x 10** (75%)	180 cm2 bottom 180 cm2 top
105K: value understood by some from the bad text of Table 6 of IEC61439-1	**1 x 100x10** (31%)	**1 x 110x10** (34%)	**2 x 80 x 10** (50%)	180 cm2 bottom 180 cm2 top

I have frequently seen panel manufacturers very concerned about choosing the CB's brands. In almost 100% of the times, the choice was from a commercial point of view for license agreements between the panel builder and the CB manufacturer. I have never seen a panel manufacturer selecting this or that brand because it would lead to a more economical design using less copper and aluminum.

About performance, the quality of LV circuit breakers made by the more known manufacturers like WEG, SCHNEIDER, ABB, SIEMENS, EATON, GE, and many others is not considerably different. All of them must attend the same IEC standards specifications and tests. To maintain market competitivity they will not have very sensible differences. Most buyers are more concerned about having a product at a lower price than having quality add-ons difficult to verify. **Check in the chart below the big differences between the power dissipations of different brands. In the case of the right side part of the chart the values are 3 TIMES higher**



2. THE OPPORTUNITIES FOR NEW DEVELOPMENTS

Much more than doing tests along 25 years, doing validated design calculations I learned that the resistance of the CB as seen from the terminals, is the more important factor in defining the cost of producing a panel with CBs. The reason is that, in general, in the temperature rise test, the hottest point that will make or fail the test is more frequently the connection of the bars to the circuit breaker.

Depending on the coating of the connection, the limit value of the IEC standard is 60K to 75K of temperature rise. IEC61439-1 induces to think that the temperature rise limit specified by the manufacturer, for example 85K, is the limit to be used. This is an error because do not consider that, connected to it , is a busbar that will age faster because supports a lower value. If the CB has lower resistance (power dissipation) , the connections heat up less and you can use thinner bars to meet the temperature rise allowed in the technical standard. Other design issues like short circuit forces, dielectric aspects and internal arc are easier to solve.

3. FINAL COMMENTS

The market competitiveness of a given LV switchgear will be mainly defined when you choose the circuit breaker to use. Read Table 1 carefully and think through the possibilities. An impactful action is to use or develop circuit breakers (CB) with low power dissipation for rated currents from 1250 A to 5000 A. It is a great opportunity for a small-size CB manufacturers.

Big companies who are comfortable with less efficient technologies, where they gain money for decades, rarely invest in the way of pursuing more efficient and lower cost technical solutions. I explained about this in this article https://www.cognitor.com.br/demo1certificate.pdf .

I think this is the reason why IEC and IEEE technical standards do not even mention that equipment using less materials, saving Planet's resources, are better than less efficient ones. It's the same rationale behind the speech of world leaders that criticize wars but profit billions of dollars selling weapons. They just look for the next election and are not worried about saving the planet.

I think that the current wars have written the tombstone and caused an irreparable loss of credibility to the good “green” efforts of the last decade. The climate showed its strength in the ongoing tragedy in the State of Rio Grande do Sul in Brazil. If it were in New York or Paris maybe something would change.

They dictate what will be included in the IEC and IEEE standards. It would be very easy and quick for them to propose and put statements in IEC and IEEE standards encouraging the use of fewer materials and resources. When I say “statement” I refer to something to signalize that reducing the use of copper, aluminum, and insulators is beneficial for the environment, and this is encouraged by IEC standards.

Imagine something like:

> **Products covered by this IEC 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.**

Motivational actions like this were done in the 80s in relation to electromagnetic compatibility EMC. It became mandatory that all IEC product standards should include a statement about EMC. I saw this happen up close because at that time I chaired IEC’s Technical Committee 32. I imagine what was in mind was the issue of cyber security strategies for the protection of substations and lines.

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The author of this article is Eng. Sergio Feitoza Costa. Sergio is an electrical engineer, M.Sc. in power systems and director of COGNITOR. Read his CV and things he helped to do in the link below. It has 40+ years of experience in the design, operation and management of high power, high voltage, and other testing laboratories. After leaving CEPEL's testing labs, Sergio gained considerable experience using test simulations to support manufacturers and certification companies in substation equipment projects. He is co-author of several IEC standards and Cigrè brochures. Sergio is the author of SwitchgearDesign simulation software and DECIDIX. Sergio is also an inventor and author of a patent about use of metal foams in switchgear. He may work as a visiting researcher to help in R&D developments. More details, free publications, and training matters in the site https://www.cognitor.com.br

REFERENCES

[1] **IEC TR 60943:1998** - Guidance concerning the permissible temperature rise for parts of electrical equipment, in particular for terminals. Issued by IEC Technical Committee TC 32.

[2] **CIGRÈ BROCHURE 830 (2021)** – "SIMULATIONS FOR TEMPERATURE RISE CALCULATION". (Sergio Feitoza Costa is co-author)

[3] **CIGRÈ BROCHURE 740 (2018)** Contemporary design of **low-cost** substations in developing countries.

[4] **Article "TEMPERATURE RISE LIMITS OF IEC 61439-1** : unclear values distort the LV switchgear market. (May,12, 2023) - http://www.cognitor.com.br/IEC614391Table6.pdf

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

[5] **IEC62271-307 (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.

OTHER USEFUL REFERENCES

[6] **Article "METAL FOAM in SWITCHGEAR, switchboards & bus ducts**
http://www.cognitor.com.br/switchgearmetalfoam.pdf

[7] **ENVIRONMENTAL EFFICIENCY CERTIFICATE OF ELECTRICAL PRODUCTS (KG/MVA): TECHNICAL STANDARD & DEMO PROJECTS MANAGEMENT)**
http://www.cognitor.com.br/demo1certificate.pdf

[8] **SUBSTATIONS & LINES INNOVATIVE PRODUCTS. SMALL R&D CENTRES + TESTING LABORATORY**
https://www.cognitor.com.br/demo2Lab.pdf

[9] **ENVIRONMENTAL EFFICIENCY CERTIFICATE of electrical products (kg/MVA) . Draft of a technical standard**
http://www.cognitor.com.br/EnvironmentalEfficiencyCertificate.pdf

[10] **CIGRÈ BROCHURE 602 (2014)** Tools for Simulation of The Effects of the Internal Arc in T&D Switchgear,

[11] **IMPROVEMENT OF QUALITY OF ELECTRIC SYSTEM INDEXES:**
https://www.cognitor.com.br/IEC602822sugestionstosc32afrombrazil.pdf

[12] **Free book by Sergio "RENEWABLE ENERGY + ENVIRONMENTAL EDUCATION TO TRY TO SAVE THE PLANET"** https://www.cognitor.com.br/educationfortheplanet.pdf

[13] **Free book by Sergio "SWITCHGEAR, BUSWAYS & ISOLATORS & SUBSTATIONS & LINES EQUIPMENT"**
https://www.cognitor.com.br/Book_SE_SW_2013_ENG.pdf

[14] **Free book by Sergio" PROJECT SAVE RIO IN 10 YEARS:**
https://www.cognitor.com.br/saverioENG.pdf

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INITIAL TERMS OF REFERENCE SUGGESTED BY SERGIO TO CIGRÈ

PROPOSAL FOR THE CREATION OF A NEW WORKING GROUP

WG Nº	Written by: Sergio Feitoza Costa E-mail sergiofeitozacosta@gmail.com

Title of the Group: TEMPERATURE RISE LIMITS INCREASE (for lighter products)

Background : According to the World Economic Forum 2022 a main issue is the "failure to mitigate climate change". Also, in the top5 is the "natural resources crisis". Both are behind the Energy Transition efforts. Cigrè and IEC are the main world voices, of the electric power industry. Their visibility facilitates to expose objective practical examples in the direction of saving natural resources. Technical standards do not yet signalize or encourage the use of fewer materials such as copper, aluminum, and other materials. For products fabrication and use, standards are still focused, as 50 years ago, in being approved in severe tests. Specifications are rarely associated to a useful life of less than 40 years.
The "Temperature rise test" is decisive to define the weight of conductors materials used in the products design. The easier items to see this are switchgear of any voltage (e.g., IEC 61271 series). However, this applies also to from big transformers to single substations busbars. From ultra-high voltage to low voltages, all of them use the same materials. Mostly, the "hot spots" that define if the product will pass or not in the temperature rise test are the connections between busbars and to other components like circuit breakers and disconnectors. The temperature rise limits of hot spots depend on the materials and not on the type of product. This is easier to see in Table 14 of IEC62271-1 which define values like 60K (bare connections) or 75K (silver or nickel-coated). As the design and objectives are not to go above limits, if you have higher limits, you can use less weight of conductors materials. If limits used today could be increased in only some 10 to 15K, this would mean a weight reduction around 25 to 35%. It is difficult to find bibliography to understand how the limits were stablished in the past and if the knowledge available today would enable their desirable increase. A key to define limits is to associate them to a time life, like 50 years. Was this approach used in the past? IEC TR 60943 enables to calculate aging when equipment is used above the limits but do not give parameters to know if limits could be increased. 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). To achieve WG goals, testing simulations would enable to do in a fast and easy way the needed design verifications.

Scope : The objective of the WG work is to assess if the temperature rise limits used in IEC standards – for connections and contacts (only) could be increased and by how much. The steps would be:

- Raise the history that led to the limits used today (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 (worldwide questionnaire and consultation with experts IEC, IEEE, etc...)
- Survey of the existence or not of systematic problems with aspects of temperature rise. Focus in switchgear. If there are few problems possibly limits can be increased (questionnaire)
- 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.

Deliverables :
Technical brochure, summary in Electra and other publications, Tutorial

Time Schedule: start: November 2023 **Final report**: Late 2025

1 Relevant literature

2 A3 - Brochure Cigrè 602 (2014) - Tools for simulation of the internal arc effects in HV and MV switchgear

3 A3 – Brochure Cigrè 830 (2021) - Application and Benchmark of Multiphysics Simulation Tools for Temperature Rise Calculations

4 B3 – Brochure Cigrè 740 - Contemporary design of low-cost substations in developing countries

5 IEC TR 60943 - 1998 - Guidance concerning the permissible temperature rise for parts of electrical equipment, in particular for terminals.