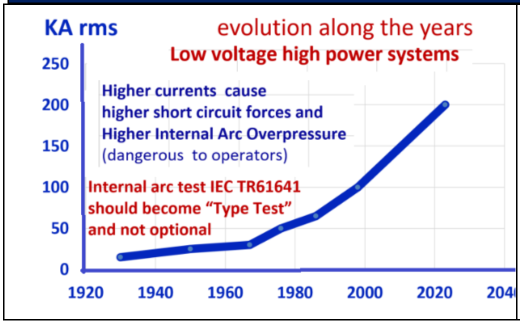
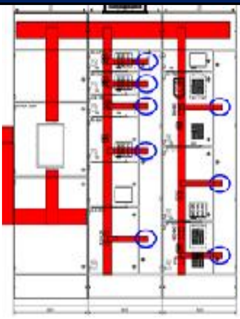
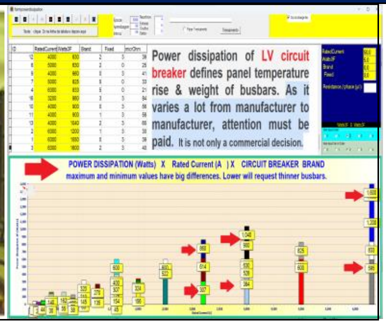
LV CIRCUIT BREAKERS: why to develop them with lower POWER DISSIPATION

A great opportunity for small-size manufacturers.







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

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1. WHY TO DEVELOP A LV CIRCUIT-BREAKER WITH LOWER POWER DISSIPATION ? WHY DO THEY HELP SAVE THE PLANET'S RESOURCES?

First of all, equipment developers and researchers need to be aware that people and companies who are comfortable with less efficient technologies, where they gain money for decades, will put up obstacles in the way of pursuing better technical solutions. This can be done, for example, preventing international technical standards like IEC and IEEE from mentioning that equipment using less materials, saving Planet's resources, are better than less efficient ones.

Basically, it is a fact of the same nature as to why, in today's world, much more is invested in selling weapons of war than in creating better conditions for the almost impossible salvation of the Planet. These today wars have caused immense loss of credibility to the good "green" efforts of the last decade. Credibility became rare.

Large global manufacturers like **ABB, Eaton, GE, Hitachi, Schneider, and Siemens**, some 60 years ago, were the catalysts of the evolution of the electric industry from. They invested in knowledge, R&D centers and in big testing laboratories. It was due to their efforts and merits and the long-term vision of some countries, that the electrical industry grew with creative solutions for the time, but which today could be much more efficient using less materials.

These big manufacturers are nowadays in the comfort zone of selling licenses to replicate those old designs of less efficient products, in less developed countries. They know well how to create more efficient solutions. If nowadays even individuals like me, could easily create products with lower wight and resources **(less kg/MVA),** think how easy it would be for their competent R&D teams. Furthermore, the main players in the IEC management are these same large manufacturers. If they present and motivate more efficient products, everyone will follow their good examples.

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.

ABOUT LOW VOLTAGE (LV) CIRCUIT-BREAKERS (CB) POWER DISSIPATION

Through temperature rise test simulations, it is simple to show that CB resistances determine the hottest locations observed throughout the testing. These 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 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.

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.

Because it was written without the barriers of major publications, the document that best explains 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.

Soon, a Cigrè working group will 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. It will check the history that led to the limits used today in technical standards and the duration of useful life associated with. It will survey of the existence or not of systematic problems with aspects of temperature rise.

The fact is that, **if a manufacturer wants to make an impactful innovation, a great opportunity is to develop circuit breakers (CB) with low power dissipation for rated currents from 1250 A to 5000 A.** It is not that difficult to design. With open mind, a good understanding of technical standards, temperature rise sound concepts and existing computational tools it is possible in some 1,5 years to arrive to an innovative design. Most stages up to the final laboratory tests can be verified by – much cheaper than lab tests - testing simulation tools.

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.

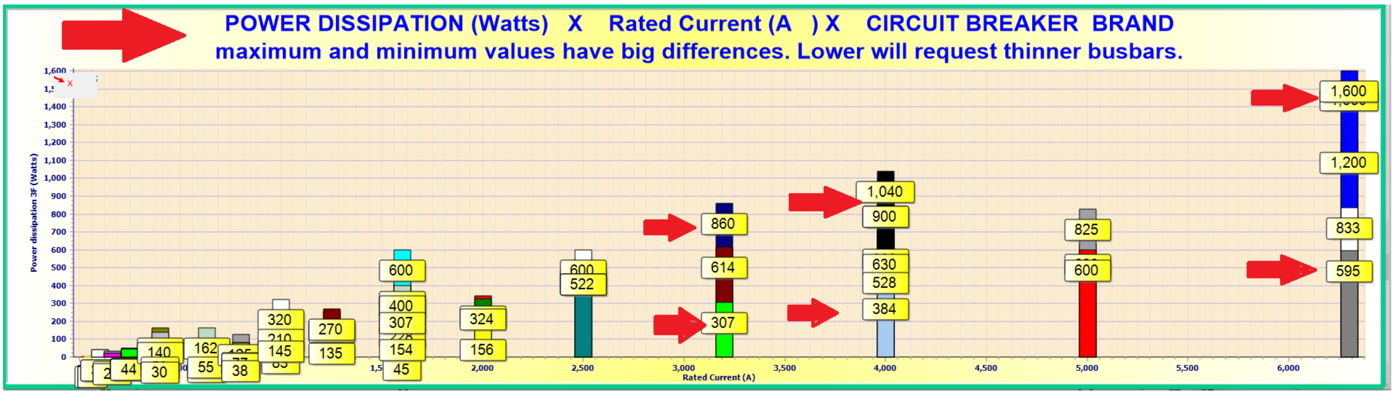
Possibly, a manufacturer who designs a switchgear panel for a 75K rise will lose the bid to one who designs it for 95K or 105K. More than this, as circuit breakers are frequently the main heat sources, the less power they dissipate, the lower will be the temperature rise and weight.

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 3ϕ = 3 x R x 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 (wrongly) 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..



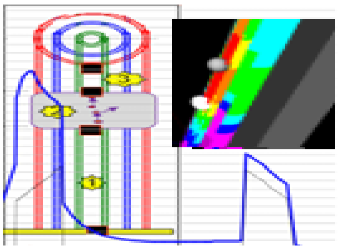
2. THE IMPACT OF THE CB POWER DISSIPATION IN THE TEMPERATURE RISE TEST AND THE OPPORTUNITIES FOR NEW DEVELOPMENTS

Doing design calculations and tests 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 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. If the CB has lower resistance, 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.

Observing the chart above, the power dissipation of circuit breakers of different brands varies from manufacturer to manufacturer, reaching twice or 3X more. The temperature rise will be greater for circuit breakers with higher power dissipation. In these cases, more weight of copper or aluminum must be used to meet the same temperature rise limit.

Thus, the 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. As mentioned, an impactful innovation is to develop circuit breakers (CB) with low power dissipation for rated currents from 1250 A to 5000 A. It is not that difficult to design. As written in the question of the article title, here is a great opportunity for a small-size manufacturer.



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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. More details, free publications, and training matters in the site https://www.cognitor.com.br

If you need a visiting researcher to train your R&D team and to help in the development of innovations write to the contact e-mail below.

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

[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)**
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Site https://www.cognitor.com.br

Contact e-mail: sergiofeitozacosta@gmail.com

Linkedin profile (30K followers) : linkedin.com/in/sergiofeitozacosta

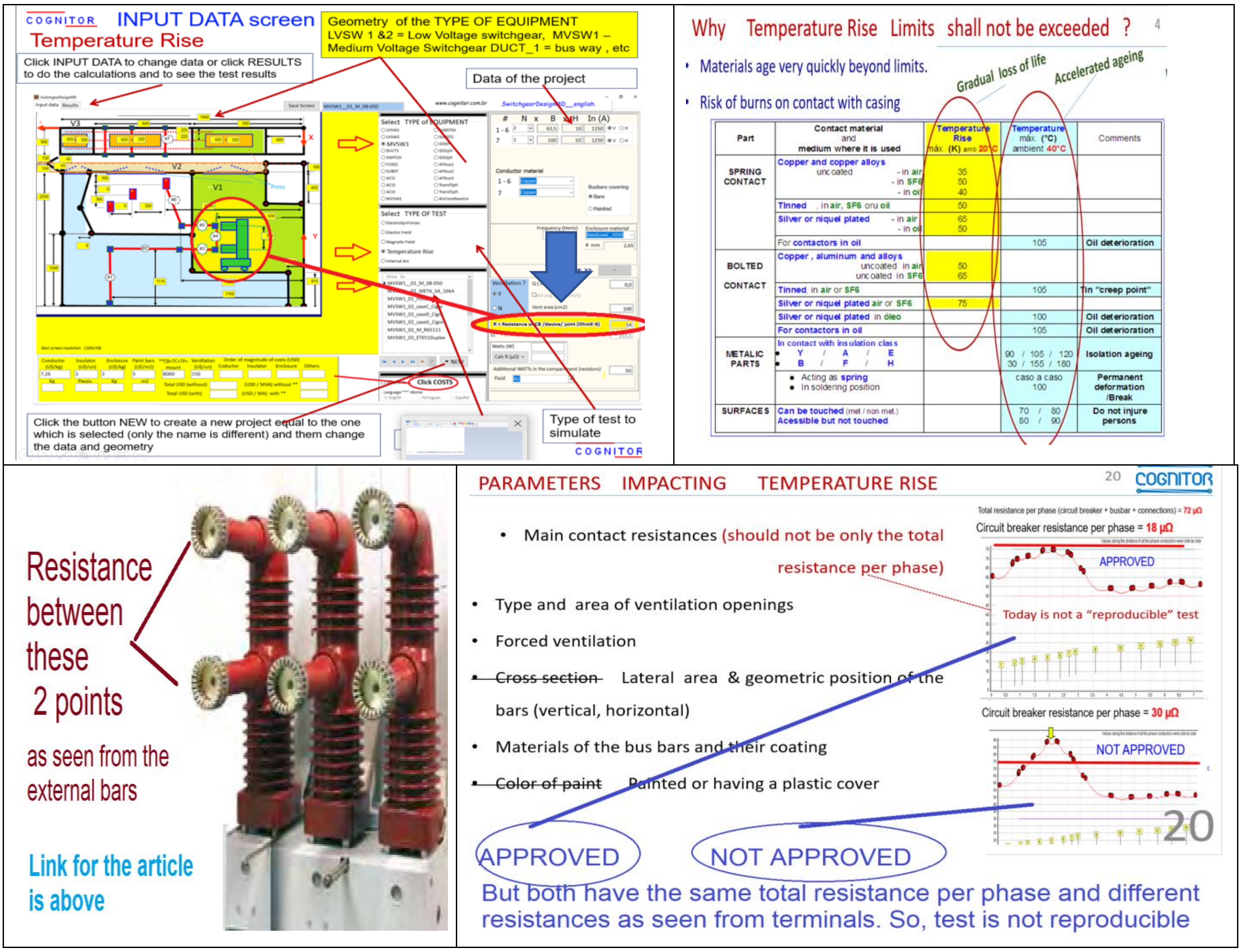
ANNEX (Complementary information not related to LV Circuit Breakers)

ABOUT THE DIFICULTIES TO FIND THE MICROOHMS (μΩ) VALUES OF HV CIRCUIT BREAKERS

When doing a design review for a manufacturer, the resistance values of MV/HV/LV circuit breakers are necessary. However, it is frequently difficult to find them explicitly in the manufacturer's catalogues. When you call the manufacturer, the salespeople must consult the "engineering" because have no idea of the importance of this data or where to find it. This has happened to me dozens of times.

Seems that even the manufacturers have difficulties to understand their importance. Still today IEC standard request in the temperature rise test to measure the total circuit resistance per phase and not (also) the CB resistance. Without doing this the test is not reproducible.

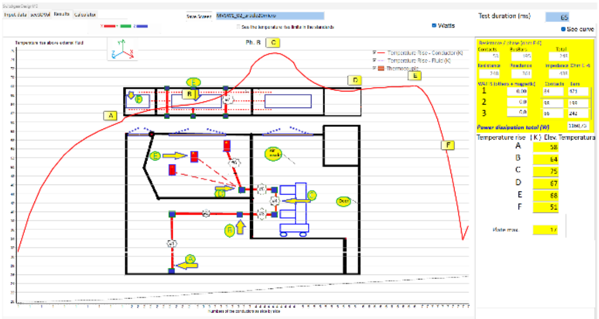
Another reason for having this information is that after receiving the supplied HV circuit breaker, the resistance will be the main reference to follow up on predictive maintenance. The "artificial intelligence" knowledge rules used for predictive maintenance system need always use this data. If you have difficulties to obtain the resistance values ask for the manufacturer, report of temperature rise test of the circuit breaker alone.

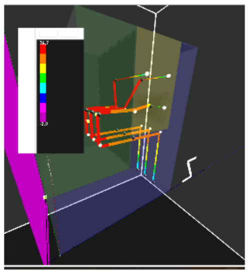


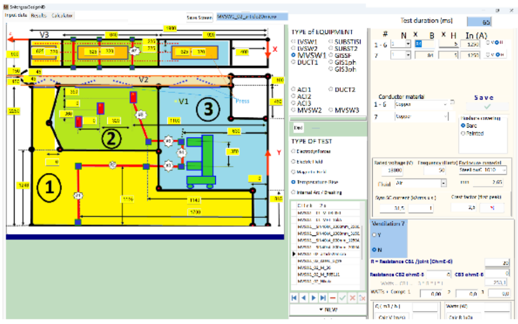
EXAMPLE OF IMPACT OF THE RESISTANCE OF THE CIRCUIT BREAKER IN THE BUSBARS THAT FEED IT Panel 1250 A – 1 bar per phase – temperature rise limit 75K – Copper bare bars.

In MV circuit breakers it was easy to see that if you use a CB with a "tighter" setting in the temperature rise tests you will have a lower temperature rise in the test because the resistance is lower than in the normal use. For this reason, it should be mandatory in the temperature rise tests to measure both the total resistance of the circuit and that of the circuit breaker alone. For the same total resistance value, you can pass or fail the test, depending on the setting. In other words, temperature-rise tests are not reproducible without the two measurements.

Resistance of the circuit breaker per phase (microOhms)	Cross section of the busbar to reach 75K in the connection	**Weight of copper %**
20 µΩ	84 x 5mm	**100 %**
50 µΩ	114 x 5 mm	**135 %**
80 µΩ	163 x 5 mm	**184 %**







Cell phone. 55-21-9 88874600
E-mail: sergiofeitozacosta@gmail.com Site: http://www.cognitor.com.br