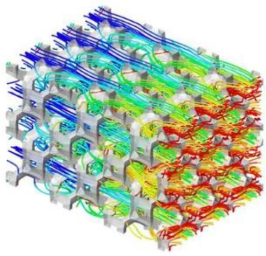
METAL FOAM in SWITCHGEAR, switchboards & bus ducts:

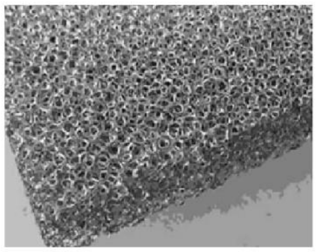
Why didn't I think of this .. before other panel manufacturers?

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

This article describes an impacting idea of using metal foam to increase the rated currents, reducing the weight of products for substations. The initial development was possible with the software SwitchgearDesign because laboratory tests would have a considerable cost. Comparisons are made by parameters USD / MVA and KG / MVA. *This idea is patented as below.*

Author: Sergio Feitoza Costa COGNITOR – Consultancy, Research and Training Ltd. E-mail: sergiofeitozacosta@gmail.com Site : www.cognitor.com.br



- High heat transfer allows using less weight of conductors for same temperature rise.
- Excellent IP degree. Does not block airflow like conventional filters and barriers.
- Use on ceilings, walls, ventilation openings and even on conductors.
- Use in internal arc depressurization flaps (good heat absorber)

1. INTRODUCTION

The use of metal foams in ceilings, depressurization flaps, walls, ventilation openings and even in busbars break old paradigms on how to build switchgear, switchboards and busducts. The concept leads to less weight, less use of expensive materials and greater energy efficiency.

After 25 years working in high-power testing labs, I have learned, from manufacturers, that the main barriers for developing new products are the initial tests to demonstrate that a new concept works. When I managed CEPEL's (Brazil) labs I could test ideas, for our own use, like using very high currents coaxial ducts, to do short circuit tests only possible with very low impedances of the busbars. Medium and small-size manufacturers do not have this possibility. This is the reason why most of them even do not start the development of ideas.

In the last 20 years I have been using and developing my software Switchgear Design to simulate those tests at a cost less than 5% than the tests in labs. Aftr collaborating with dozens of manufacturers, to develop power products, all over the World, I am convinced that a simulation tool is much more useful than a real testing lab in all the stages before the final type tests. The final tests are essential to expose small details that cannot be detected by testing simulations. They are also essential to get a formal test report to be used in the commercialization.

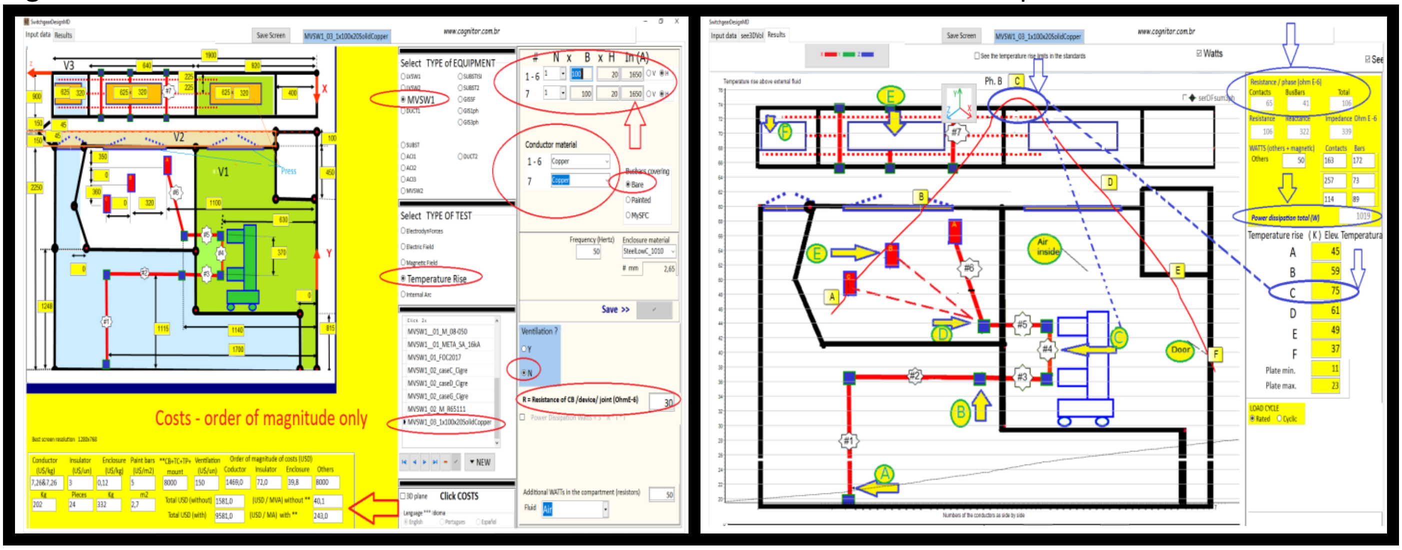
The development of this idea was possible because a simulation tool could be used. To do the same using real lab tests would require some 500K Euros. Rare companies would assume the risk of doing this and eventually having an unsuccessful result. The world-wide big manufacturers could do it but are in the comfort zone of selling less efficient designs and seems not interested in bringing innovations to the market.

This idea is an original application for switchgear. I did not use tricks to exaggerate the attractiveness of the idea. I mentioned it in a recently published book, and it is now properly registered as a patent. The concept is to use metal foams in ceilings and even in busbars, instead of the conventional solid materials.

<u>In this article I will explain only the more difficult to assimilate type of use which is in the conductors.</u> The use in ceilings is a much easier and attractive option. However, I am still doing calculations and a laboratory test to be sure that these supposedly good applications are good.

For the comparisons, for the use in busbars, I took, as reference, an AIS conventional switchgear, designed with solid 100x 20mm copper bars supposing a local short circuit level of 40 kA-1s. I calculated the current that would cause a 75K temperature rise, in the connection of the busbar to the circuit breaker (Figure 1), during a temperature rise test. I also calculated the currents which would produce the same 75K in two other alternatives – *having the same weight of solid copper bars* - with 2 x 100 x 10 mm and 3x 100 x 6.6 mm. I did the same for a *copper foam 100x20 mm*.

Figure 1 – Reference case with solid bars 100x20 mm – current 1650 A – C.B. 30 µΩ – 75K in the C.B. terminals



The weight per length (kg/m) of a metal foam bar depends on the porosity of the foam, I used a foam with a density of 1g/cm3. The density of a solid copper bar at 20°C is 8,9 g/cm3. So, the 100x 20mm bar made of metal foam has a weight around 11% of the weight of a solid copper bar.

When constructing a switchgear many factors influence the final cost. I considered the ones highlighted with an arrow in the lower part of the Figure 1, from SwitchgearDesign. I assumed that the circuit breaker has a resistance 30 µΩ, as seen from terminals.

The parameter used to compare the construction costs of the alternatives, was the USD /MVA, where the parcel MVA = 1.732*Vn x In. I will call it “transmitted power”. The current is the one related to the 75K. The value USD is an order of magnitude of the sum of the main cost components.

I estimate that the international price of a switchgear depending on the rated voltage between 15 kV to 36 kV is around some USD 21.000, 00 to USD 45000,00. The construction cost values obtained for the alternatives were around 50% of this. The results are presented in Table 1.

To avoid complex discussions, I considered the aspects of temperature rise and electrodynamic forces during short circuits. The aspects of dielectric performance and even internal arc are not difficult to manage. To maintain the article short, I will not present them. For internal arc, an idea is presented in the Conclusions.

2. TEMPERATURE RISE AND SUPPORTABILITY TO SHORT CIRCUIT FORCES OF METAL FOAM BUSBARS

Temperature rise is the dominating aspect to define the design of most equipment. To use a metal foam busbar, require more than knowing the physical properties, as we do with solid bars. Most of the properties are the same or very close although the literature about metal foams is not yet so easy to understand.

For the electrical conductors we have in mind the known equation. ___ $R = \rho * L / S$ ___ where R is the resistance of a length L of a conductor of cross-section S and ρ is the resistivity of the material. The value R is used to calculate the Joule generation $R * I^2$.

To do the calculations with SwitchgearDesign I used finite volumes methods considering the losses by convection and radiation. If you take a look in the equations of pages 151 to 153 of this my book https://www.cognitor.com.br/Book_SE_SW_2013_ENG.pdf will notice, in the bottom-right of page 133, that such losses are proportional to the lateral area (S_{lat}) of conductors exposed to the fluid. Notice that they are not related to the cross section as many designers think.

A larger lateral area implies that more heat will be removed from the conductor leading to a lower temperature rise. Also, we shall take care of the resistances of connections. In this article I considered a conventional copper silvered connection with a temperature rise limit of 75K.

Metal foam bar is not like a regular solid profile. To calculate the cross-section (S), the perimeter (P) or lateral area (S_{lat}), to use in the calculations, is not like solid bars. You need to consider that the exposed area for heat dissipation is much higher than a solid conductor.

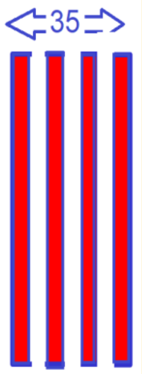
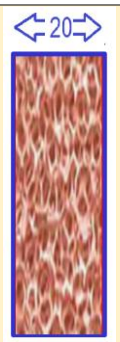
The electrodynamic short circuit forces are other aspect to consider. The calculation methods are the same. However, to calculate the supportability of the bars to bending we need to know an equivalent "moment of resistance (section modulus)" and the tensile strength of the bar. I also did some non-conventional approaches to increase the mechanical strength of the profile.

3. ABOUT THE IP (INGRESS PROTECTION) ISSUES

This is another impacting aspect of the use of metal foams. Just looking to the photos, we can percept that, except for the ingress of water, not difficult to manage with external solid barriers, the IP degree that may be reached comes close to the solid plates. A relevant aspect is that the metal foams, with a proper porosity, does not block airflow like conventional filters and barriers.

When you use conventional filters for dust you strongly impeach the passage of the air flow. So, more ventilation power is necessary. More ventilation power means more difficulties to block the passage during internal arc tests. The results that can be obtained with metal foam in the place of conventional filters are very significant. Some few laboratory tests can show the advantages.

Table 1 – Comparison of the design alternatives. VN is the rated voltage 17,5 kV . In is the current related to a temperature rise of 75K ******* The lower is U$/MVA transmitted the higher is the efficiency and good use of materials

Copper bars per phase	Bars per phase	Current giving 75K in connection (Ampere)	Same total Weight of Copper (kg)	Kg / MVA	U$ / MVA
1 x 100 x 20 mm		**1650 A** (No vent. openings)	202	**14**	**243**
2 x 100 x 10 mm		**1940 A** (No vent. openings)	202	**12**	**207**
4x 100 x 5 mm		**2290 A** (No vent. openings)	202	**10**	**175**
Metal foam copper bar 4x 100 x 5 mm (200 cm2 ** natural ventilation with foam)		**2250 A** (With a opening without forced ventilation)	22	**7**	**155**

4. RESULTS AND FINAL COMMENTS

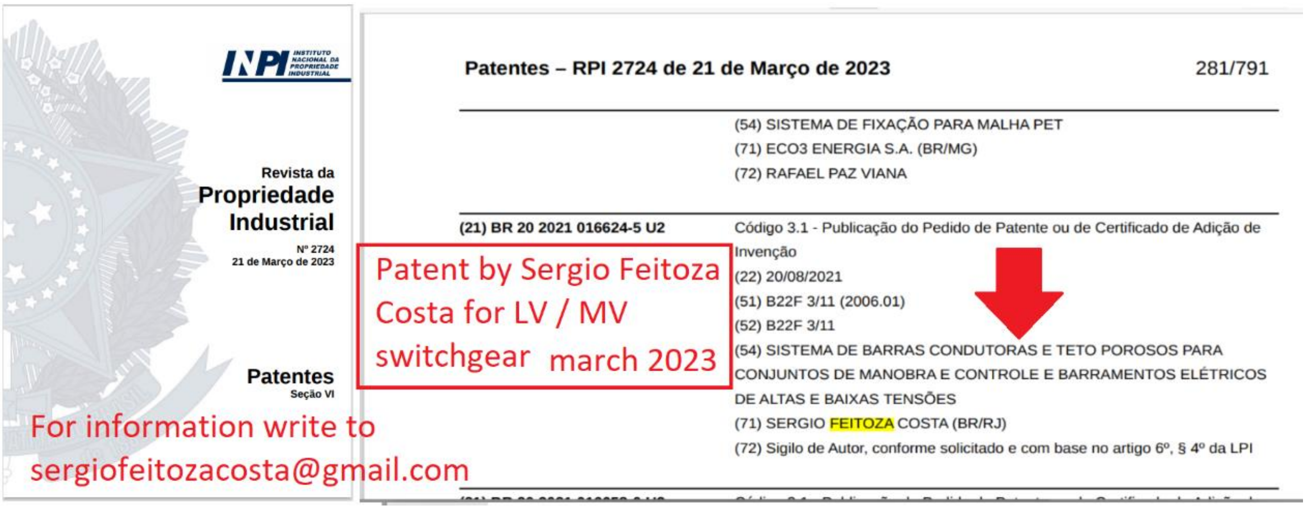
Looking to the results in Table 1 we can percept that metal foam is an open door for impacting – immediately- the market of switchgear / switchboards and busways. The values of U$/MVA and KG/MVA show obvious costs and efficiecy advantages. This is not an academic approach . This is immediate industrial application.

As soon as this application of metal foam increase the price of metal foam bars will reduce by scale sales making the advantages much bigger. There are many variants of the idea that I will not detail here.
One of them is using in the ceilings and depressurization windows, a plate of metal foam properly designed to reduce temperature rises. It will also work as an efficient heat absorber during internal arc tests.

If any manufacturer wishes to explore these ideas write me and I can help effectively with all the technical details that I cannot disclose here. I can demonstrate that the calculation results are correct. My feeling is that in less than one year we will see commercial products using these techniques, as an alternative to the conventional solid busbars.

My expectation is that, soon, we will see many manufacturers, all over the World, saying why didn't I think of this ... before other panel manufacturers?

The patent: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(54) SISTEMA DE FIXAÇÃO PARA MALHA PET
(71) ECO3 ENERGIA S.A. (BR/MG)
(72) RAFAEL PAZ VIANA

(21) BR 20 2021 016624-5 U2
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(71) SERGIO FEITOZA COSTA (BR/RJ)
(72) Sigilo de Autor, conforme solicitado e com base no artigo 6º, § 4º da LPI

Patent by Sergio Feitoza Costa for LV / MV switchgear march 2023

For information write to sergiofeitozacosta@gmail.com

For more information, please write to Sergio Feitoza Costa **E-mail sergiofeitozacosta@gmail.com** .

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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. 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 lab experience + test simulations to support manufacturers and certification companies.

He is the author of SwitchgearDesign for testing simulations and DECIDIX for technical economical assessment of energy projects. Sergio was chairman of IEC Technical Committee 32 and is coauthor of IEC 62271-307 & IEC60282-2. In CIGRÈ is, coauthor of Cigrè brochures 602 (Internal Arc), 740 (Substations) and 830 (temperature rise). Sergio is also, in the free moments, book writer, songs composer & musician.

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