# LV & MV switchgear: The old tables for current capacity have changed for much better !!! but many designers do not know.

Link English version https://www.cognitor.com.br/OldTablesENG.pdf

**Author**: Sergio Feitoza Costa COGNITOR – Consultancy, R&D , Training.

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**THE OLD TABLES**

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Table 6-34 (continued)

Copper conductors of rectangular cross-section in indoor installations, ambient temperature 35 °C, conductor temperature 65 °C. Conductor width vertical; clearance between conductors equal to conductor thickness; with alternating current, phase centre-line distance ≧ (4 to 6) × clearance between phases

| Width × thickness | Cross-section | Weight[1]) | Material[3]) | Continuous current in A a.c. up to 60 Hz, painted, no. of conductors 1 | 2 | 3 | 4 (50[2])) | bare, no. of conductors 1 | 2 | 3 | 4 (50[2])) | Continuous current in A d.c. and a.c. $16\frac{2}{3}$ Hz, painted, no. of conductors 1 | 2 | 3 | 4 | bare, no. of conductors 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| mm | mm² | kg/m | | \| | \|\| | \|\|\| | \|\| \|\| | \| | \|\| | \|\|\| | \|\| \|\| | \| | \|\| | \|\|\| | \|\|\|\| | \| | \|\| | \|\|\| | \|\|\|\| |
| 50 × 5 | 249 | 2.22 | E-Cu F 37 | 697 | 1 140 | 1 330 | 2010 | 583 | 994 | 1 260 | 1 920 | 703 | 1 170 | 1 370 | | 588 | 1 020 | 1 300 | |
| 50 × 10 | 499 | 4.44 | E-Cu F 30 | 1 020 | 1 720 | 2 320 | 2 950 | 852 | 1 510 | 2 040 | 2 600 | 1 050 | 1 830 | 2 360 | | 875 | 1 610 | 2 220 | |
| 60 × 5 | 299 | 2.66 | E-Cu F 30 | 826 | 1 330 | 1 510 | 2 310 | 688 | 1 150 | 1 440 | 2 210 | 836 | 1 370 | 1 580 | 2 060 | 696 | 1 190 | 1 500 | 1 970 |
| 60 × 10 | 599 | 5.33 | E-Cu F 30 | 1 180 | 1 960 | 2 610 | 3 290 | 989 | 1 720 | 2 300 | 2 900 | 1 230 | 2 130 | 2 720 | 3 580 | 1 020 | 1 870 | 2 570 | 3 390 |
| 80 × 5 | 399 | 3.55 | E-Cu F 30 | 1 070 | 1 680 | 1 830 | 2 830 | 885 | 1 450 | 1 750 | 2 720 | 1 090 | 1 770 | 1 990 | 2 570 | 902 | 1 530 | 1 890 | 2 460 |
| 80 × 10 | 799 | 7.11 | E-Cu F 30 | 1 500 | 2 410 | 3 170 | 3 930 | 1 240 | 2 110 | 2 790 | 3 450 | 1 590 | 2 730 | 3 420 | 4 490 | 1 310 | 2 380 | 3 240 | 4 280 |
| 100 × 5 | 499 | 4.44 | E-Cu F 30 | 1 300 | 2 010 | 2 150 | 3 300 | 1 080 | 1 730 | 2 050 | 3 190 | 1 340 | 2 160 | 2 380 | 3 080 | 1 110 | 1 810 | 2 270 | 2 960 |
| 100 × 10 | 988 | 8.89 | E-Cu F 30 | 1 810 | 2 850 | 3 720 | 4 530 | 1 490 | 2 480 | 3 260 | 3 980 | 1 940 | 3 310 | 4 100 | 5 310 | 1 600 | 2 890 | 3 900 | 5 150 |
| 120 × 10 | 1 200 | 10.7 | E-Cu F 30 | 2 110 | 3 280 | 4 270 | 5 130 | 1 740 | 2 860 | 3 740 | 4 500 | 2 300 | 3 900 | 4 780 | 6 260 | 1 890 | 3 390 | 4 560 | 6 010 |
| 160 × 10 | 1 600 | 14.2 | E-Cu F 30 | 2 700 | 4 130 | 5 360 | 6 320 | 2 220 | 3 590 | 4 680 | 5 530 | 3 010 | 5 060 | 6 130 | 8 010 | 2 470 | 4 400 | 5 860 | 7 710 |
| 200 × 10 | 2 000 | 17.8 | E-Cu F 30 | 3 290 | 4 970 | 6 430 | 7 490 | 2 690 | 4 310 | 5 610 | 6 540 | 3 720 | 6 220 | 7 460 | 9 730 | 3 040 | 5 390 | 7 150 | 9 390 |

**To pass in the test you need $\Delta T_{max}$ 60 to 75K in the connections and not in the busbars.**

$\Delta T = 65 - 35 = 30K$

(in the busbars)

[2]) Minimum clearance.

[3]) Material: E-Cu or other material to DIN 40 500 sheet 3, preferred semi-finished material: flat bars with rounded edges

## 1) THE OLD TABLES DO NOT CONSIDER CONNECTIONS - WHAT MOST DEFINE THE TEMPERATURE RISE

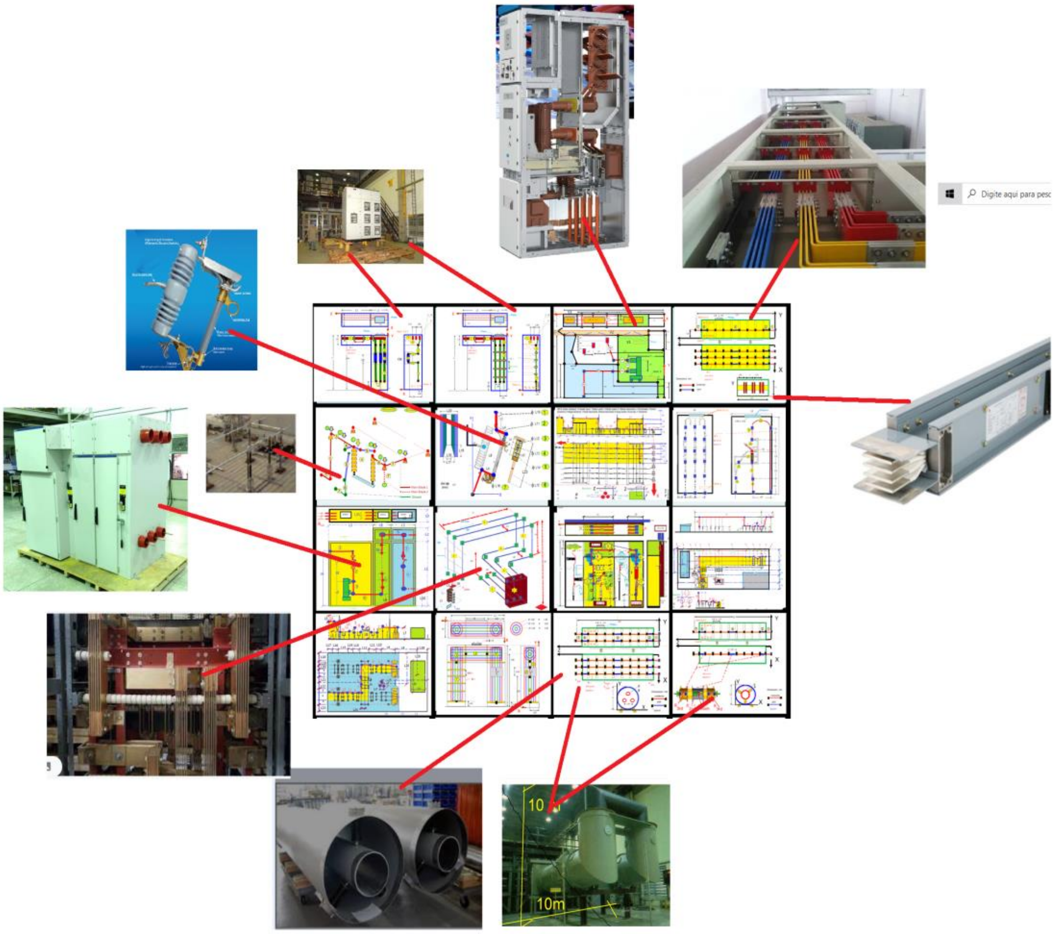
Many designers ask me to update those old tables that have been for decades in good engineering manuals from Siemens, ABB and Schneider. I used them when I was a young engineer. I even used it to help design the busbar systems for CEPEL's high-power and high-current laboratories. There are busbars for up to 50kAef permanent and 300kAef / 750kAcr short circuit. In commercial electric panels and busways, we reach usually around 7500 A. The most common currents are in the range of 800 to 4000 A.

At that time, 45 years ago, I had not developed the SwitchgearDesign software to calculate quickly, within a few hours of learning, temperature rises, short circuit forces and internal arc overpressures. These are the most costly aspects of the projects. I developed the tool to be able to design faster without depending on the very expensive tests carried out in laboratories. Tests are expensive because installations of this type require high investments. In South America, unfortunately, there is only one large laboratory, CEPEL. The other, in Itajubá – MG, which I helped design since the feasibility study, would correct this deficiency in the Brazilian electrical industry. However, the project was ready and in full construction when it was interrupted in 2019.

I am one of the few professionals who has had the experience of carrying out real lab tests and also creating and using simulators of those tests with identical results. I have learned much more about engineering concepts, design and technical standards in the last 20 years doing test simulations than I did in the 25 years before doing tests and managing large laboratories.

So, pay attention in next lines. There is a lot of experience behind this text.

**THE NEW TABLES ARE LOW-COST SOFTWARE, EASY TO USE AND TAKE INTO ACCOUNT THE GEOMETRY OF THE ELECTRIC PANEL, LOCATION OF USE, COATINGS, VENTILATION, POWER DISSIPATION, PARTITIONS, ETC...**



Recently another consultancy customer asked me to update the busbar sizing tables used in their company. I explained that type of practice leads to oversizing. This was not relevant in the past, in the times of fat cows. However, today there are many more manufacturers competing in the market and using less copper and aluminum makes a difference.

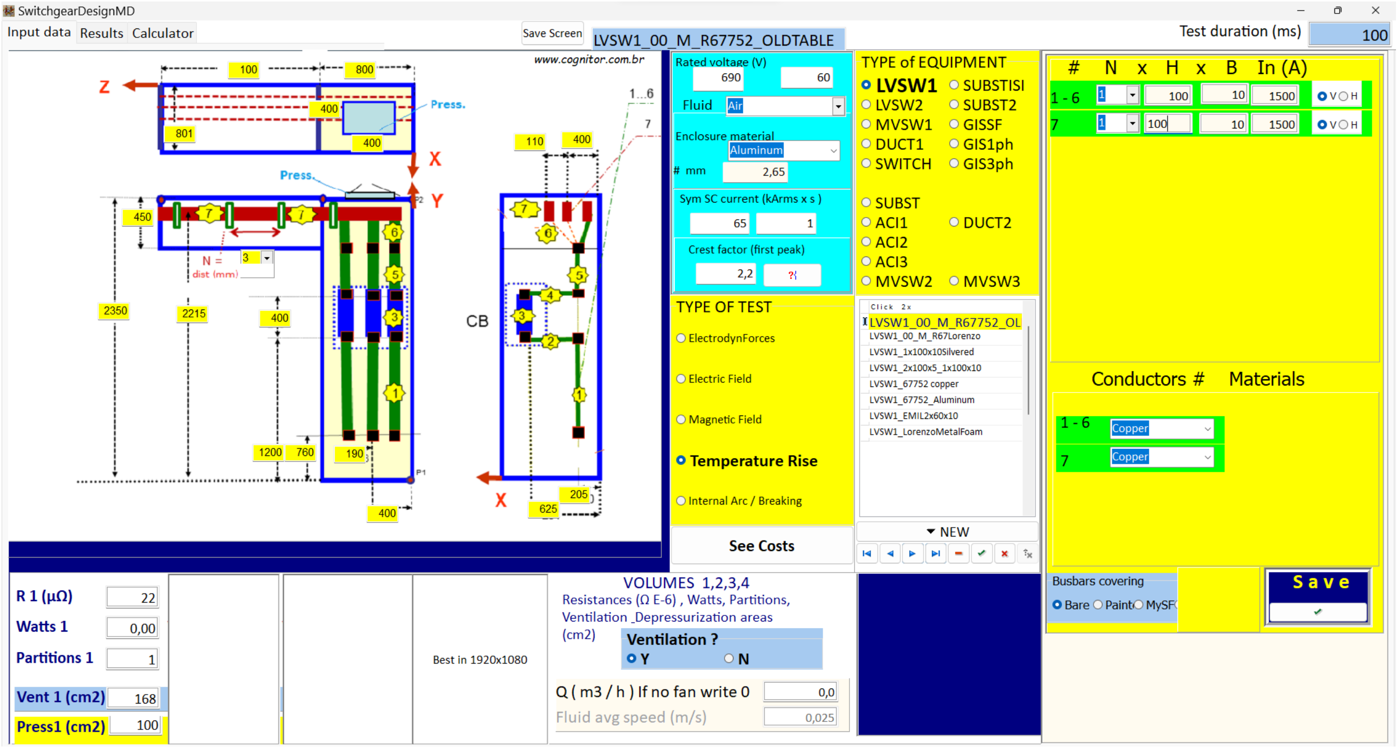
The old tables, like the one in the figure above, were outdated because they did not consider important data such as connection resistances and contacts of circuit breakers, switches, and fuses. This is the main design parameter to define temperatures. The focus of most projects is to pass the type tests of IEC62271 and IEC61439 standards. I learned this over the last 20 years by doing many calculations and simulations and studying the document IEC TR 60943 - Guide on permitted temperature rise for parts of electrical equipment, in particular for terminals.

The problem of the old tables is that they were created solely with the aim of calculating the maximum current that you can pass through a busbar, without connections, to cause a temperature rise in the busbar, for example, $\Delta T = 65 - 35 = 30K$. The focus of those who design electric panels and busways is to obtain temperature rises in the range of 60K to 75K at critical points, generally connections. The temperature of the bars, outside the connections, does not matter in the criteria for the switchgear or switchboard to be approved in the temperature rise test.

We will compare what the project would be if using the old tables or using a low-cost, simple-to-use calculation tool.

## 2) THE PROJECT TO DEFINE AND THE RESULTS OBTAINED BY OLD TABLES AND THE NEW TOOL.

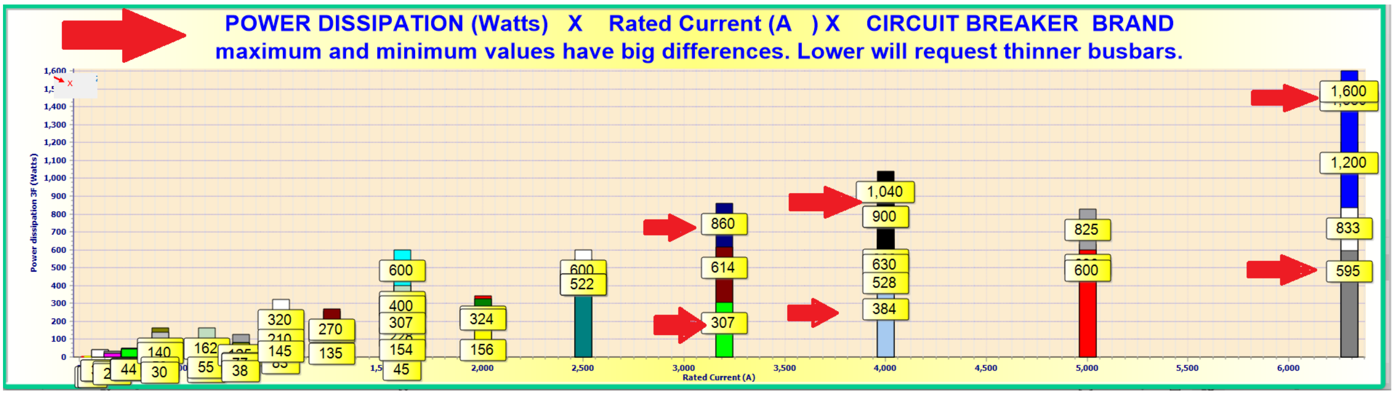
Let's assume that the designer's objective is to develop an air-insulated panel with the dimensions shown in the following figure for a rated current of 1500 A. The panel has a natural ventilation opening measuring $168cm^2$. The material of the bars is copper, and they are not painted. The connections are also bare, that is, without coating silver, tin or nickel-plated.



In this project, the resistance per phase of the circuit breaker seen from the terminals varies greatly depending on the brand of circuit breaker. In the following figure we see that for a 1500 A BT circuit breaker the dissipated powers can vary from 150W (22.0 µΩ) to 600W (88.0 µΩ). These variations will lead to very different busbar size values for the same temperature rise.

Note that circuit breaker resistances can vary greatly from manufacturer to manufacturer. This is disregarded in the old tables and in IEC61439-1. Furthermore, each screwed connection between bars has 7.0 µΩ.

Read the reference article [2] and you will understand why.




For a situation like this, passing the temperature rise test means having a maximum temperature rise at the connections of 60K. These are the values clearly explained in the IEC62271-1 and IEC 60943 standards. The poorly written and confusing table 6 of IEC61439-1 (low voltage switchgear) leads designers to think that the values could be 85K or even 105K. This is a gross mistake in the text of this standard that even leads to problems in bidding because the higher the limit used; the less conductor material is used. If a connection between two bars supports 75K on one side and 85K on the other side, the limit that the laboratory must consider saying whether or not it passed the test is the lowest, which will age first. In this case 75K and not 85K. If a manufacturer designed for 85K in connections, it has an advantage over another that designed (correctly) for 60 or 75K.

A barrier created by the experts who wrote IEC61439-1 is the new temperature rise test method. The one previously used in the IEC 60439 series (TTA/PTTA) standards was more practical and intelligent. It was inexplicably replaced by the IEC61439-1 method, which eliminated the possibility of carrying out the test from many laboratories around the world, especially in developing countries. The change makes no practical sense because there are many variants of similar projects. It only served to make life difficult for small and medium manufacturers. The large manufacturers, who write the standard, benefited. For small and medium-sized, paying for expensive tests is a barrier. At the very least, there was a failure to realize that outside of developed countries there are far fewer testing laboratories and resources. In the Reference article [1] I show the details.

## DIMENSIONING USING THE OLD TABLES

The most frequent practice is very simple. The designer goes to the busbar table and chooses the current closest to 1500 A without worrying that the table clearly states an increase of 65-25 = 30K on the busbar, and nothing about the temperature rise of the connections.

Therefore, looking at the old table above, one would choose one bar per phase of 100x10mm (1x100x10mm). You wouldn't be considering what's most important and you wouldn't have any idea what would happen during the test. It could be approved because it used more material than necessary, or you could not pass because used less.

## DIMENSIONING USING AN EASY TO USE CALCULATION TOOL FOR 60K TEMPERATURE RISE ("NEW TABLE" )

Below we show, for three different brands of 1500 A circuit breakers, the busbars that would be chosen using the complete SwitchgearDesign calculation for 1500 A and ΔT max = 60K. We also show the temperature rises that would occur using the 100x10mm bar calculated by the old table. Note that depending on the brand of circuit breaker the results are very different from using the old table.

| | Power dissipation of circuit breaker WATTS = 3 x R x I $^{2}$ (R per phase μΩ) | | |
|---|---|---|---|
| | 150W (22,0 μΩ) | 300W (44,0 μΩ) | 600W (88,0 μΩ) |
| Temperature rise **ΔTmax** with bar **1x100x10 and** 1500 A | 50 K | 68 K | 100 K |
| Busbar that would cause **$\Delta T_{max}$ = 60K** with 1500 A | **1x90x10** | **1x120x10** | **2x120x10** |

## 3) FINAL COMMENTS

The table above clearly shows that when using the old tables, depending on the dissipated power of the circuit breaker, one may be under sizing or, in most cases, oversizing the project when using copper or aluminum. It's an unnecessary exercise in trying your luck. I would say that nowadays, at least 60% of designers around the world still use the old tables because they are unaware of the new tools, which are much simpler and faster to use. Understand how simple it is to use the "new table" in this YouTube video. YOUTUBE https://youtu.be/Lr83T7jH9Ow

## REFERENCES


- [1] Table 6 of IEC 61439-1: Questions to TESTING LABORATORIES and CERTIFIERS:

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

- [2] LV CIRCUIT BREAKERPOWER DISSIPATION: defines LV switchgear cost.

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

- [3] Book "ELECTRICAL PANELS, BUSBARS AND OTHER EQUIPMENT FOR SUBSTATIONS" (also in English and Spanish)
- https://www.cognitor.com.br/Book_SE_SW_2013_ENG.pdf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This article was written by Sergio Feitoza Costa, electrical engineer, M. Sc in Power Systems.

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