IEC 61439-1 TEMPERATURE RISE LIMITS: unclear values distort the LV switchgear market and are a source of errors in the fair analysis of bids prices. (My,12, 2023)

with 2 questions to major certification companies and testing laboratories

- Limits "specified by manufacturer" are not an objective neutral statement. They depend only on the materials used and not of unclear statements made by manufacturers. Why not replacing the badly written IEC61439-1 Table 6 with the competent IEC62271-1 Table 14 ? Is the reason technical or commercial ? Check Annex 2 about what is written clearly in IEC 60943
- In case you have a connection between a component like a CB and a feeding busbar the maximum limit of the connection is the lowest of the two values – and not the value of the circuit breaker. (IEC60943)
- If a silvered busbar connection has a limit 75K and the terminal of the circuit breaker supports 85K the limit of the connection for saying that passed or not in the test – just using the common sense – is 75K.

  Who is formally responsible for the bad use of limit values in case, for example, of a fire started by overtemperatures ?

Author name: Sergio Feitoza Costa

Affiliation: COGNITOR – Consultancy, Research and Training Ltd.

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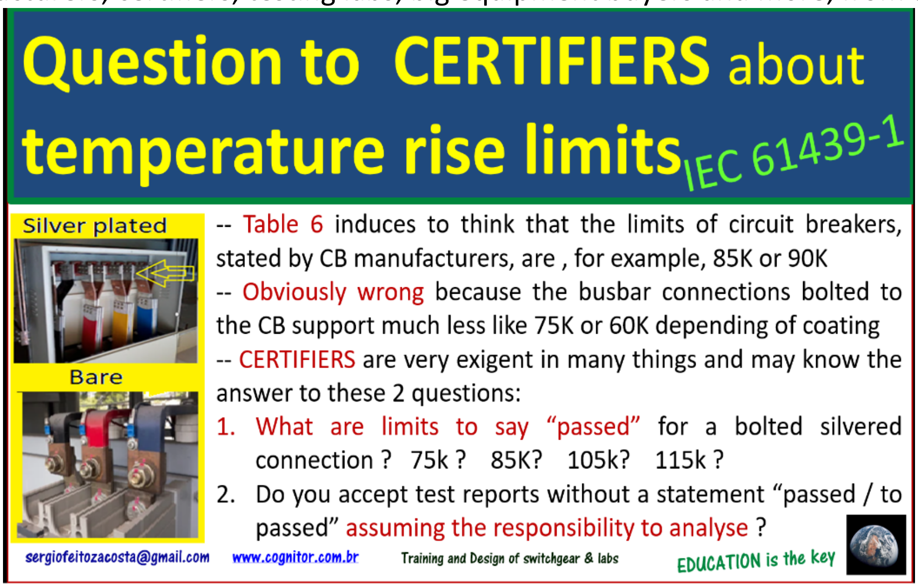
A QUESTION TO CERTIFIERS AND TESTING LABS

As I did not receive answers from the IEC experts that prepare the technical standard, I will start with two questions to CERIFICATION COMPANIES AND TESTING LABS . They are possibly the most well-prepared experts to answer these questions. This is a post sent to some 26000 followers. They include the main switchgear manufacturers, certifiers, testing labs, big equipment buyers and more, from all over the World.



TEMPERATURE RISE TEST IS THE MAIN FACTOR THAT IMPACTS THE COST OF A POWER EQUIPMENT

I have been alerting to this critical point of the IEC61439-1 in the last 10 years when wrote the article, "The Mystery of the Temperature Rise Limits" (link at the end) . I frequently receive the same question from clients like power equipment big users, certifiers, testing labs and LV switchgear manufacturers. Actually, I have this question since the time I managed the big Brazilian testing labs, 25+ years ago. My orientation, as manager, was always to include a statement in the test reports telling "passed or not passed".

In my point of view, when a 3rd part laboratory issues a report without including the statement (passed or not passed) , it gives the false impression that the equipment has passed the test, even if it has not. I would like to see the big certifiers and laboratories writing publicly about this, but I never see.

A simple question is : what temperature rise is permitted, during the test, for the connection between the busbar and the terminals of the main circuit breaker? If a silvered busbar connection has a limit 75K and the terminal of the circuit breaker supports 85K the limit of the connection for saying that passed or not in the test – just using the common sense – is 75K. Who is formally responsible for the bad use of limit values in case, for example, of a fire started by overtemperatures ?

In the well detailed table 14 of IEC 62271-1 (MV switchgear) the value is 75K (silvered or nickel coated connection) or 60K, if bare. The values depend only on the materials of the bars and coatings used. This is well explained in IEC60943: - "Guidance concerning the permissible temperature rise for parts of electrical equipment, in particular for terminals". This excellent IEC TR was published by the first time in 1989 when I was the chai of IEC Technical Committee 32 (TC32).It is a must for electrical and mechanical engineers.

So, again, I remember this unanswered question to the experts of IEC MT 2 (Maintenance of IEC 61439-1, IEC 61439-2, IEC/TR 61439-0, IEC/TR 60890, and IEC/TR 61641 – link in IEC site). The text below will facilitate them to understand the bad consequences of what they wrote in that table. I found a link with the names of MT2 members is at https://www.iec.ch/dyn/www/f?p=103:14:23685049488833::::FSP_ORG_ID:10644

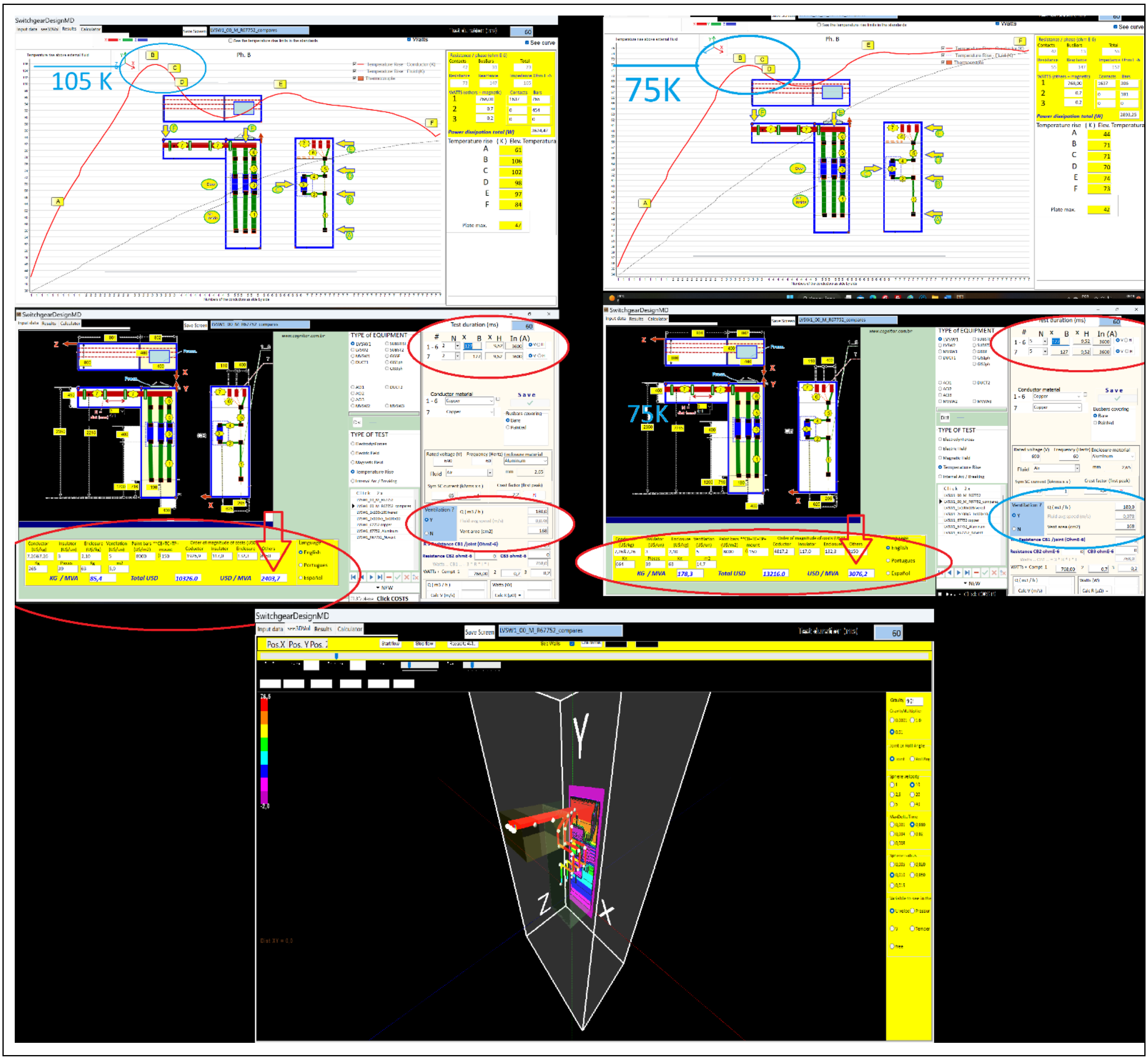
REASONS FOR THE DOUBT ABOUT THE RIGHT VALUE TO CONDIDER IN TABLE 6 OF IEC 61439-1 :

- Table 6 - note g states maximum temperature rise limit of 105K for copper busbars and conductors.
- The 3rd line of the table "Busbars and conductors" do not state anything useful for a testing laboratory, to take conclusions, doing the test. It is not their responsibility to analyze the materials and coatings. By the way, several sentences in that table go against the principles of the old ISO9000 (verifiable, reproducible, clear).

The problem is that an equipment designed to attend 105K, even using ventilation, will have a production cost some 75% than another one designed for 75K. More than this , according to the formulas of IEC 60943 the connections would have at least 50% lower time life (check calculation pages 113-115 of the book – link in the end).

So, a 105K equipment has lower cost of production and connections shorter time life than a 75K one.

Here is the aspect which cause the obvious distortion in bid processes. This is the reason why most test reports circulating in the market do not have a **"passed / not passed" statement** written by the lab. Reports without conclusions are an open door to deviations.



EXPLAINING SOME MORE DETAILS

In IEC standards, a temperature rise of 105 K means that , in an ambient air temperature of 40°C , the temperature will be 40 + 105 = 145°C . By table 14 of IEC62271-1 a temperature rise of 75K in the connections of the circuit breaker to the busbars, usually the hot-spot in switchgear, means 40 + 75 = 115°C

Reading the table 6 and notes, we are induced to think that the limit for connections is 105K or that , as in Note F “, the temperature-rise limits have to be specified by the original manufacturer. The confusion become complete when in Note G there is a mention to a 105 K temperature rise for bare copper conductors, but nothing is said about aluminum.

A temperature rises of 105K means a temperature of 40 + 105 = 145°C . So, considering that, from the point of view of temperature rise, low voltage and high voltage switchgear are exactly equal and use same materials, IEC62271-1 accepts a temperature of 115°C while IEC61439-1 accepts 145°C . As there is no technical reason for the difference, one of the two standards is wrong. Looking to many other IEC standards the only one different of all is IEC61439-1.

In my opinion, in the past someone confused the term temperature rise (K) with temperature (°C) and, as in the fable " The Emperor's New Clothes " by Hans Christian Andersen, this became the truth for the specialists of the IEC61439 series. It is time to recognize that something is wrong and to do the corrections. By the way, there could be just one table of temperature rise limits for all IEC products standards. All of them could just refer to the values of IECTR 60943 in a sentence like. "For the limits of temperature rise, table 6 of IEC 60943 applies. To accommodate the things IEC could update, for example, the value of 75K by 85K or 90K. This is proved by the user's experience. Certainly, nowadays no one will invest millions to check if the best value is 75K or 85K or even 105K.

– 66 –IEC 62271-1:2017+AMD1:2021 CSV

Table 14 – Limits of temperature and 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 (Refer to points 1, 2 and 3 in 7.5.6.2) (Refer to NOTE 1)	Maximum value	
	Temperature °C	Temperature rise at ambient air temperature not exceeding 40 °C (NOTE 2) K
1 Contacts (refer to point 4) …………		
2 Connection, bolted or the equivalent (refer to point 4)		
Bare-copper, bare-copper alloy or bare-aluminium alloy		
– in OG (refer to point 5)	100	60
– in NOG (refer to point 5)	115	75
– in oil	100	60
Silver-coated or nickel-coated (refer to point 6)		
– in OG (refer to point 5)	115	75
– in NOG (refer to point 5)	115	75
– in oil	100	60

– 110 – IEC 61439-1:2020 RLV © IEC 2020

Table 6 – Temperature-rise limits (9.2)

Parts of assemblies	Temperature-rise K
Built-in components [a]	In accordance with the relevant product standard requirements for the individual components or, in accordance with the component manufacturer's instructions[f], taking into consideration the temperature in the assembly
Terminals for external insulated conductors	70[b]
Busbars and conductors	Limited by[f]: – mechanical strength of conducting material[g]; – possible effect on adjacent equipment; – permissible temperature limit of the insulating materials in contact with the conductor; – effect of the temperature of the conductor on the apparatus connected to it; – for plug-in contacts, nature and surface treatment of the contact material
Manual operating means:	

f For temperature-rise tests according to 10.10, the temperature-rise limits have to be specified by the original manufacturer taking. It is the responsibility of the original manufacturer to take into account any additional measuring points and limits imposed by the component manufacturer.
g Assuming all other criteria listed are met, a maximum temperature-rise of 105 K for bare copper busbars and

FINAL COMMENTS

I think that the message in this text is clear and should be considered by IEC management and by certification companies.

Standards are far from perfect texts and are improved along the time and use. It is not typical to maintain an unclear text for so many times, producing a confusion in the market. I write public articles about this for more than 8 years. Never received an answer.

After so many articles published, for so many years without answers, no one can say that they did not know the importance of this, for example in bidding. Large equipment buyers such as oil and gas companies, mining companies, power utilities and even certifiers and testing laboratories are technically well prepared to analyze these issues.

Technical standards and certification regulations have financial impacts, for example in bids and fair competition. It also involves safety aspects to persons and installations. There are previous articles about this and other themes in

https://www.cognitor.com.br/Downloads1.html

Just to register, this short article was posted in Linkedin by Sergio Feitoza Costa on April 6 – 2023 and reviewed and posted again in May, 12 - 2023

https://www.linkedin.com/in/sergiofeitozacosta/

ANNEX 1 -REFERENCES:

C.V: https://www.cognitor.com.br/Curriculum.html

Check my CV and things I helped to do

http://www.cognitor.com.br/HelpedToDo.pdf ….

Training material : https://www.cognitor.com.br/trainingENG.pdf

Free Book useful to understand the concepts explained in this article.

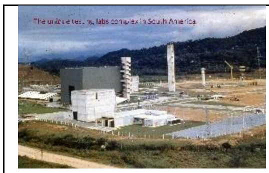
"Switchgear, Busways, Isolators - Substations & Lines" (available also in Spanish and Portuguese)

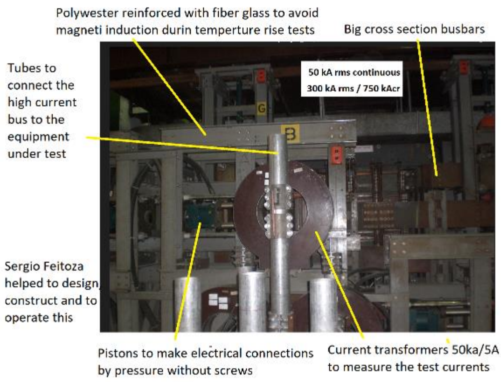
https://www.cognitor.com.br/Book_SE_SW_2013_ENG.pdf (check from page 92 to 123)

Link for this article:
http://www.cognitor.com.br/IEC614391Table6.pdf

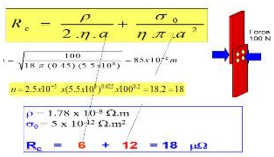
Annex 2 - ABOUT COATING and BRUSHING OF BUSBARS and IEC60943

A client asked me advice regarding working with brush over the end part of bars to get better the conductivity in the connection surface with junctions. I remembered the old times of the preparation of the busbars of the high current testing laboratories that I helped to design, to construct and operate. At that time, we did not use the sophisticated machines which are available today for this kind of work.





At high current installations as 50kA rms permanent we use even pistons, polyester structures and stainless-steel screws to avoid high magnetic induction and resistances. MV & LV switchgear more than 4000A require careful design.



Rio de Janeiro – RJ – Brazil - CEP 21931-220 *** Phone . 55-21-9 88874600
E-mail: sergiofeitozacosta@gmail.com Site: http://www.cognitor.com.br

Then I went to my reference document for matters of contacts and connections IEC TR 60943 - Guidance concerning the permissible temperature rise for parts of electrical equipment, in particular for terminals. IEC 60943 has been prepared by IEC technical committee 32: Fuses. It was published by the first time when I was the Chairman of IEC Technical Committee 32 (TC32).

There , designers may find very useful information that I will resume here including some notes / observations.

" **3.5 USAGE AND PRECAUTIONS TO BE TAKEN IN THE USE OF CONTACT MATERIALS**.
Bare copper tends to deteriorate considerably with time and temperature. It is unwise to exceed 60 °C to 85 °C

> Note by Sergio: as the reference temperature is 40ºC, this means a temperature rise, as used in the tests, of 20K to 45K. It is very frequent for designers to do a confusion between the terms "temperature" and "temperature rise". The experts that prepared the confusing test of Table 6 in IEC6149-1 should read this and revise the text of that table which causes a market confusion, Check article of Reference [3] above.

These values are to be determined according to the use of the metal in the contacts and connections and according to the nature of the atmosphere. … As an interesting example, we may calculate the resistance of copper and of nickel-plated, tinned and silver-plated copper contacts for a contact force of 10 N and after 1 000 h exposure to ambient air … . The following values are presented in table 4 for the contacts resistance aged.

Material	Resistance in mΩ
Bare Copper	20
Nickel-plated copper	25
Tinned copper	6,8
Silver-plated copper	0,3

From table 4, the advantages of tinning or silver plating are clear. Nickel-plating only appears interesting for polluted atmospheres where silver-plating would be unsuitable. Considering the different possibilities in more detail:

a) Nickel-plated copper is suitable in the case of corrosive atmospheres or high temperature contacts, a frequent situation in certain power stations or in railway transport. B
b) Tinned copper and tinned aluminium are the preferred materials for low voltages. The low hardness of tin is interesting in so far as it gives low contact resistances. … . Special attention should be given when the temperature of tin exceeds 105 °C, especially when mated with silver-plated contacts, because of the creep phenomena which occur above this level.
c) For flexible or bolted tinned contacts subject to vibration, a "fretting corrosion" phenomenon may occur on the tin plating, rapidly leading to the destruction of the contact, even in the case of low currents compared with the rated current; it may be preferable in this case to use bare, silver-plated, or nickel-plated contacts.
d) Silver is an excellent contact material which ages slowly except in atmospheres with sulphurous fumes.
e) Aluminium cannot be used unless its layer of insulating alumina is removed by brushing with grease or by other special treatment recommended by the manufacturer.

5.2 Temperature and temperature rise of …. components.

5.2.1 Factors on which temperature rise values are based. The values in table 6 (of IEC60943) … have been assessed as follows.

- **For the permissible temperature rises:**

either from long duration tests corresponding to a normal life of about 20 to 40 years, and hence from the values confirmed by experience; …. or from short duration tests at high rating, the lifetime at normal rating having been deduced from rules of ageing … In this case, the mean temperature Θe of the air surrounding the component corresponds to the standard mean ambient temperature Θan of 20 °C.

- **For the maximum temperatures not to be exceeded**

… consideration of the properties of the materials and components (for example, creep of tin at over 105 °C), the ambient temperature to be considered is the maximum temperature Θan of 40 °C.

The considered values are … indications…. For a more precise determination it is necessary to consider:

– the operating conditions (continuous, cyclic, for 8 h, etc.) and the thermal time constants of the components.
– the operating modes (bimetallic strips which can attain high temperatures, contacts close to fuses, etc.);
– the type of installation (inside one or more enclosures);
– ambient temperature different from "standard" (e.g. tropical zones with ambients possibly up to 50 °C);
– the methods of use, and of the conductor-terminal connections.

5.2.2 Maximum temperatures and permissible temperature rises (need to distinguish between two groups)

Column A – Those corresponding to components susceptible to ageing, but whose rapid destruction temperature is high; for example, the temperature rise of copper contacts is limited to 35 K even though they can withstand a temperature of almost 150 °C without immediate destruction. It is evident that in this case the ambient temperature to be used is the mean temperature during the life of the component, i.e. 20 °C in most cases.

For components subject to ageing such as contacts, the period of normal life will therefore depend upon the temperature rise specified in the standards, and on a temperature Θe of 20 °C of the medium surrounding the component.

Column B – Those corresponding to components whose temperature must not exceed a certain value, otherwise very rapid, if not immediate, destruction will occur:
in this case, the ambient temperature to be taken into account is 40 °C. This applies for example to certain insulation materials, tinned contacts (creep point of tin: 105 °C), springs, etc.

Table 6 (IEC60943) gives typical values used in standards, making the distinction between the maximum permissible temperature rise at Θc = Θan = 20 °C and the maximum permissible temperature for Θan = 40 °C.

For individual items of equipment, the values may be slightly different, due to the special needs of each individual item.

LINKS ABOUT BRUSHING OF BUSBARS (Search brushing of copper busbars)

https://www.beienebusbarmachine.com/products/intelligent_3d_busbar_processing_center/imac_center_80/intelligent_busbar_processing_center_imac_center_6000.html?gclid=EAIaIQobChMIzKmOx9_y_gIVBCjUAR2xgAdZEAAYASAAEgJKgfD_BwE

http://p537794.webspaceconfig.de/wp-content/uploads/2019/11/Copper-for-Busbars.pdf

https://www.youtube.com/watch?v=ukL13Gv87sk

https://www.youtube.com/watch?v=rSaoD5C1gWY

Article - High Quality joints https://www.researchgate.net/publication/50346033_High_quality_joints_of_copper_bus_bars