Design of IEC62271 & IEC61439 products: (from the training)

Connections: Silver /Tin/Nickel plated X Bare

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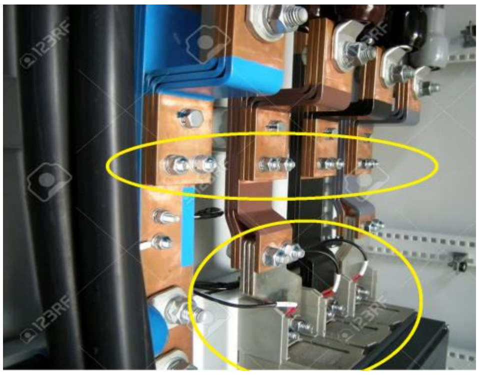
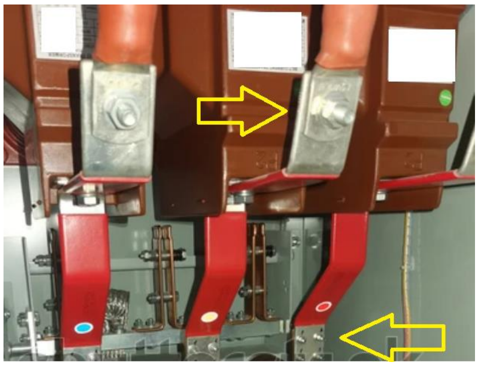




1) kG/MVA: A PERFORMANCE INDICATOR FOR TECHNICAL-ECONOMIC COMPARISONS.

It is an error of judgment, very common among panels and busbar manufacturers, just saying that it is more advantageous to make the bare connection. The world has changed, and coating is much easier today than it was in the past. The same applies to brushing the ends of busbars (read Annex2 specially Table 4).

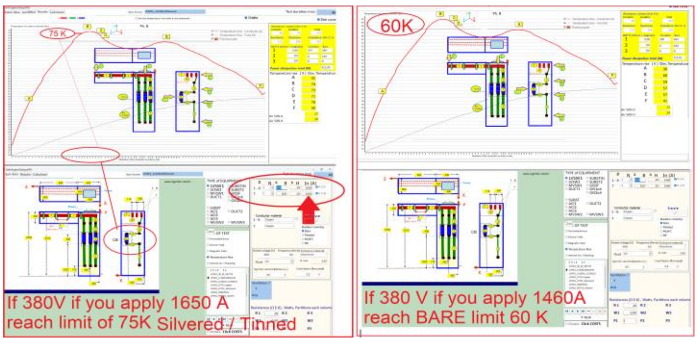
To make a more complete analysis it is necessary to first consider that the main objective is to be approved in the temperature rise test. The allowable temperature rises limits for bolted connection, silver or nickel-plated (75K), tin-plated (65K) or bare uncoated connections (60K) are quite different. The higher is the limit permitted by the standard, more current you can transmit in a given cross section. Therefore, to pass the test, you can apply more current to a coated busbar than to a bare one. This means that you can, for the same current, design your equipment to use thinner bars in coated busbar than in bare busbar.

In this article I will do a comparison using the key temperature rise limits of :
60K: the limit for bare uncoated busbars
75K : the limit for silver or nickel-plated.

In addition, just for informative purposes, I will calculate also for
50K : The previous limit of bolted bare connections before the last revision of IEC62271-1
85K : A value frequently used by manufacturers of LV switchgear based on the false assumption that in a circuit breaker / busbar connection the allowable limit is the one of the circuit breakers. This error is induced by the bad text of IEC61439-1 Table 6.

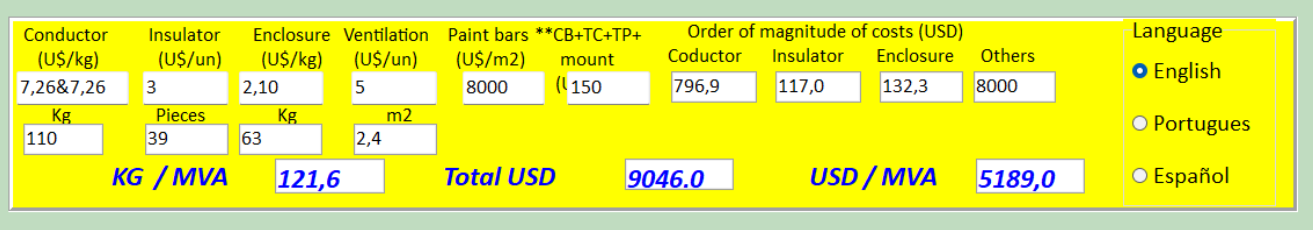
Kg/MVA is the EASIER performance indicator. We will use as the ratio between the weight of the complete equipment (or eventually the conductor's weight) and the transmitted power like MVA = 1,732* rated voltage phase to phase * current

Here, to permit a better visibility we will compare only the values of the currents that can be reached, at the maximum limit of permitted temperature rise



Most designers I know, when evaluating whether a certain design alternative is more economical, do a simplistic analysis, not thinking about the set of important variables. They think only about 1 or 2 of them. For whom wish to do a complete analysis you may use the free software Decidix in the link http://www.cognitor.com.br/c_Feasibily_Analysis.htm . It is a powerful but easy to use tool (G, T & D). Also check this link with a description of the method http://www.cognitor.com.br/ENG_Part2_Methodology.pdf .

In the testing simulation software SwitchgearDesign there is a fast analysis that works quite well. Check here a typical presentation of values.

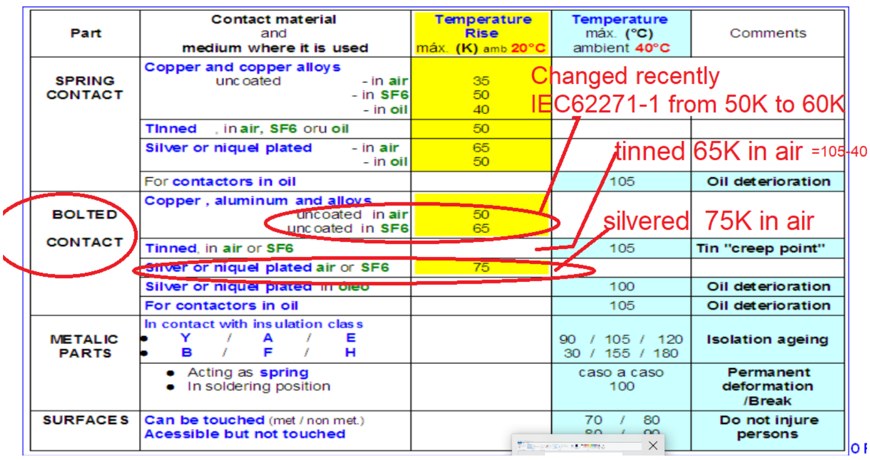


2) PREMISSES FOR USING A PLATED CONNECTION INSTEAD OF A BARE CONNECTION

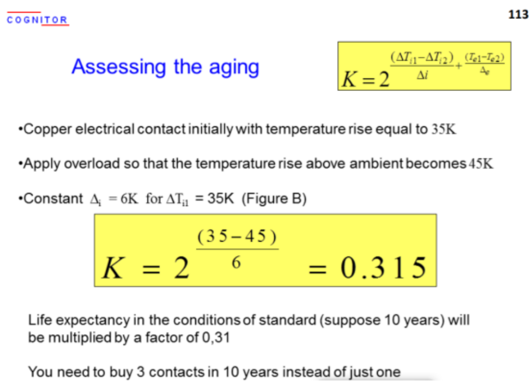
Busbar connections are a good example to understand how an incomplete analysis leads to lost opportunities to carry out more competitive projects. The simplistic reasoning is that if you use silver connections between busbars or circuit breakers you are doing a more expensive project. This is not true if you consider premises like:

a) To reach a wider market you will have to test your product to get a neutral temperature rise testing report. Buyers only feel safe when they receive a report approving the product. Use the standard in your favor.
b) According to IEC technical standards the permitted temperature rise in a silvered or nickeled connection is 75K while in a bare connection it is 60K [IEC 62271-1 / 2017] .Notice that in the 2011 version was 50K. For tinned is 65K. I imagine that in the near future this value will become 75K.
c) Using a temperature rise at a connection higher than the IEC limit will bring a faster aging. For each 10K above the limit you loose 2/3 of the expected life. That means, in a period like 10 years, to buy 3 instead of 1. (Figure 1)
d) The main immediate costs associated to the product are the construction and testing costs .
e) Nowadays using plated connections raises little the cost of producing the product. There are accessible machines for plating.
f) Using a plated or bare connection have low influence in the temperature rise of the connection. The gains are in the durability and the fact that the technical standard permit a higher temperature rise in plated connections . <u>The technical standard does not specify a high-quality plating. It specifies tinned or silver or nickeled .</u> Testing laboratories use the limits written in the standard tables. Be pragmatic .
g) During a temperature rise test the hot spot point is usually in the connections of the busbars to the circuit breaker or switch or fuse. You may use plated connections only in the hotspots and bare in the others.

Figure 1



Part	Contact material and medium where it is used	Temperature Rise máx. (K) amb 20°C	Temperature máx. (°C) ambient 40°C	Comments
SPRING CONTACT	Copper and copper alloys uncoated - in air / - in SF6 / - in oil	35 / 50 / 40		
	Tinned , in air, SF6 oru oil	50		
	Silver or niquel plated - in air / - in oil	65 / 50		
	For contactors in oil		105	Oil deterioration
BOLTED CONTACT	Copper , aluminum and alloys uncoated in air / uncoated in SF6	50 / 65		
	Tinned, in air or SF6		105	Tin "creep point"
	Silver or niquel plated air or SF6	75		
	Silver or niquel plated in oleo		100	Oil deterioration
	For contactors in oil		105	Oil deterioration
METALIC PARTS	In contact with insulation class • Y / A / E • B / F / H		90 / 105 / 120 30 / 155 / 180	Isolation ageing
	• Acting as spring • In soldering position		caso a caso 100	Permanent deformation /Break
SURFACES	Can be touched (met / non met.) Acessible but not touched		70 / 80	Do not injure persons

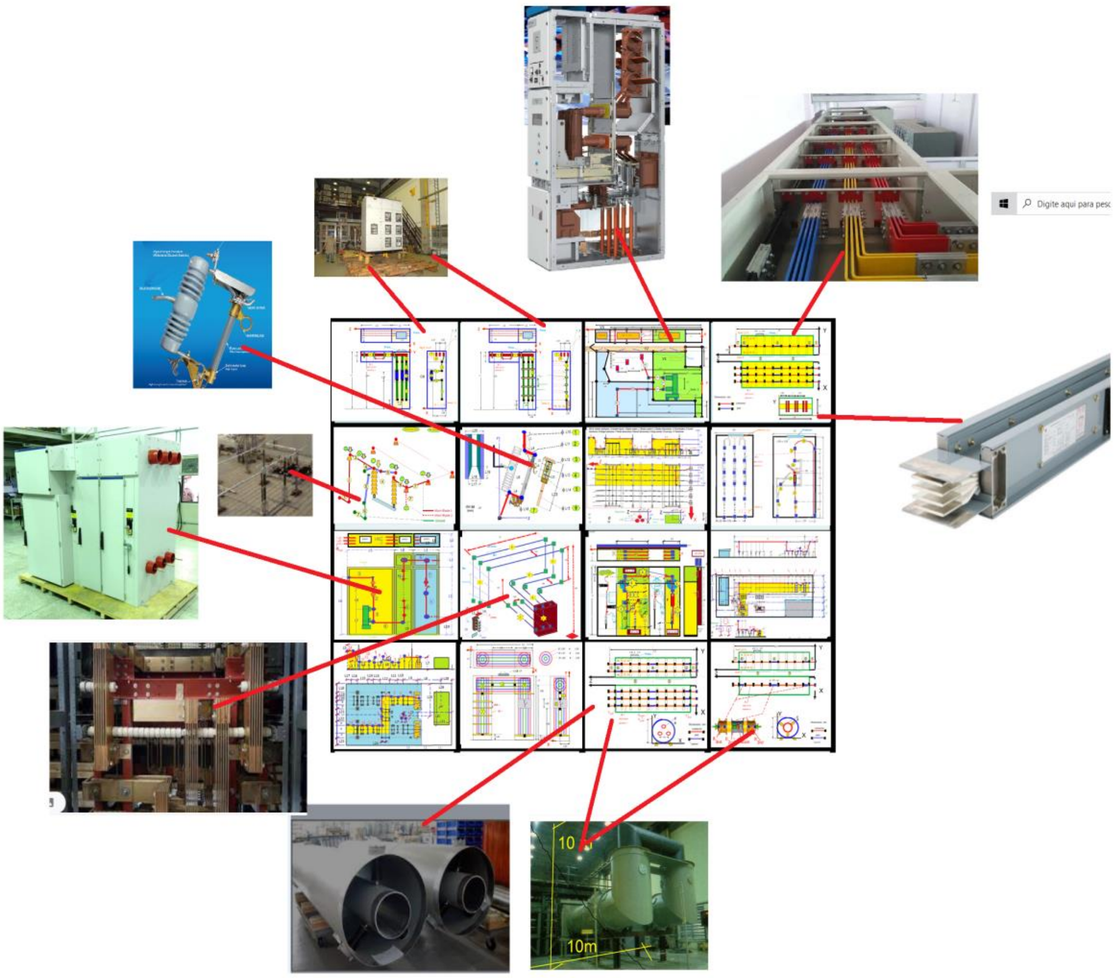


3) COMPARING THE COSTS

I used an easy to verify approach of taking the 1x100x10mm bar of the figure above and to go changing only the currents to identify the values which cause a temperature rise of 50K, 65K, 75K and 85K. So, the weight (kG) is equal in all the cases and the power P = = 1,732* rated voltage phase to phase * current is directly proportional to the current value obtained. So, the higher is the current then the lower is kg/MVA and the lower is the cost. With the software tool this can be done in minutes

Table 1 _ Results for comparisons using a 100x10mm bar and a bolted connection.

Material of the coating / plating (IEC62271-1)	Temperature rises limit in the bolted connection (K)	Current that produces the temperature rise limit
previous standard value for bare	50K	**1320 (90 %)**
Current value for bare	60K	**1460 (100 %)**
Tinned	65K	**1530 (105 %)**
Silvered / Nickeled	75K	**1650 (113 %)**



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Annex 1 - **REFERENCES**

[1] Training about Substation Equipment design & testing (Switchgear, Controlgear, Switchboards & Busways) :
https://www.cognitor.com.br/trainingENG.pdf

[2] Book "Switchgear, Busways, Isolators - Substations & Lines" (available also in Spanish and Portuguese)
http://www.cognitor.com.br/Book_SE_SW_2013_ENG.pdf

[3] Article by Sergio Feitoza Costa published once more in Linkedin posts by May,13 – 2023 : 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
Link: http://www.cognitor.com.br/IEC614391Table6.pdf

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- Free Downloads area: http://www.cognitor.com.br/Downloads1.html
- Curriculum https://www.cognitor.com.br/Curriculum.html
- Training + SwitchgearDesign https://www.cognitor.com.br/trainingENG.pdf
- Consultancy services: https://www.cognitor.com.br/proposal.pdf

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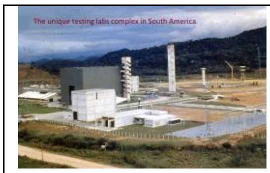
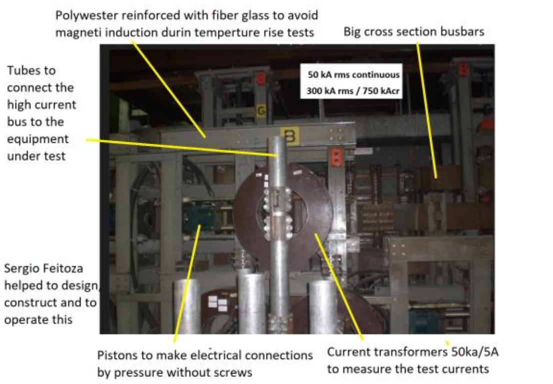
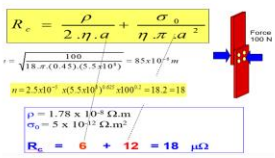
Annex 2 - ABOUT COATING and BRUSHING OF BUSBARS and IEC60943

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.



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 40°C, 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