TEMPERATURE RISE TESTS IN IEC 61439-1: Low-voltage switchgear & controlgear assemblies

(Question 1: What is the temperature rise permitted in a bolted - silvered contact? 75K or 105K ?)
(Question 2: IEC Common specifications for medium & low voltage switchgear and controlgear ?)

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1. INTRODUCTION

IEC technical standards are powerful documents providing directions for specifications, tests and types of equipment which will be commercialized in the Worldwide market. I learned this during my 40 years of activities in the electrical sector. I had the honor of collaborating actively in IEC working groups (WG) including coordinating a WG which prepared a revision of the IEC 60282-2 and, recently, as a member of the WG which prepared IEC 62271-307. In the beginning of the 90's I was Chairman of the IEC Technical Committee 32 (High Voltage Fuses). I worked 25 years in a high power and high voltage testing lab doing temperature rise tests among many others.

What is written in IEC standards will influence what will happen in the electric products market all over the World. IEC standards are predominantly made by experts from the major international equipment manufacturers. Most of them are in Europe (near the places of the meetings). There are very few participants from small and medium size companies and from outside the developed countries.

In most of the countries, especially the developing ones, the IEC standards are considered almost perfect documents. In many cases they translate those standards to the mother tongue becoming national Standard some 4 year after the publication of the original in English.

Whoever participates in the WGs preparing an IEC publication knows that IEC texts are quite far from a perfect document. They are the text that is possible to reach after the hard discussions in WG meetings. Who invest money and time for participating in the meetings will try to include in the text the points of their interest. Better standards are reached when there is, in the WG, a reasonable balance between manufacturers, testing labs and people that represents the interests of the users. It was like this in the past but in the last 15 years most of the participants in the WGs are the world's largest manufacturers.

It is essential that the IEC text is clear and objective avoiding that the reader need to understand hidden specifications between the lines. The average reader of an IEC publication has much less knowledge and information than the WG members. However, sometimes the texts end up getting confused so that they can contemplate points of view of the participants that cannot be very explicit. The consequence is that the average reader can give a different interpretation of the intent of the standard. Usually these confusions are corrected or improved in the next revision of the IEC text.

This is the central point of this article. IEC60439, from 2011, started to be replaced by the series IEC 61439. It seems that there are significant differences in the temperature rise tests. IEC 61439-1 brought the intelligent concept of design rules. It is a great advance. Could be much better if it was clear that the “design rules” concept are applicable not only to the short circuit aspect but also to temperature rise tests and others.

The recent IEC 62271-307 (medium voltage switchgear), in a certain way, followed the same basic concepts of design rules to avoid repetition of expensive laboratory tests. However, the approach in IEC 62271-307 was more complete covering aspects of short circuit, temperature rise, dielectric tests, mechanical tests and internal arc tests.

In the last two years several of my consultancy clients presented me doubts about requirements in IEC 61439-1. Even being an experient standards reader and having worked 25 years in a testing laboratory, for these types of tests, I had also doubts.

The purpose of this article is to present these doubts (Section 2). When analyzing the doubts, I received a question that I found strange at first. After analyzing the details, I realized that there may be a particularity, when performing temperature rise tests, which may lead to obtaining different test results for the same equipment and the testing conditions. I will describe the reasoning for this in Section3. In the Final Comments (Section4) I present an idea for a common clauses standard applicable to both medium voltage (MV) and low voltage (LV) switchgear.

2 THE DOUBTS IN THE TEXT ABOUT TEMPERATURE RISE TESTS IN IEC 61439-1

2.1- Maximum temperature rise permitted in bolted connections (105 K or 75 K ?)

IEC standards for MV switchgear (series IEC 62271) states clearly that for bolted connections the temperature rise limits for bare connections is 50 K and for silvered connections is 75 K. The excellent document IEC TR 60943 - Guidance concerning the permissible temperature rise for parts of electrical equipment, in particular for terminals, is the more complete IEC document on concepts of temperature rise. It presents the same values (Table 1)

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Fundaments of the values of temperature rise specified in the IEC standards

- Avoid to accept test reports which do not inform whether the equipment passed or failed the test. It may not have passed and sometimes it's hard to know without knowing well the standard
- If certain limits specified in the technical standards are exceeded parts may have accelerated aging or even destroyed in a small time

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 óleo		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 / 120 130 / 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 80 / 90	Do not injure persons

In IEC 61439-1 there is a specification which is not understandable. The intention for being so different from above texts is not clear at all and result in the following doubt:

<u>Is the temperature rise limit for a silvered - bolted connections 75K or 105K ?</u>

In section 9.2 is written: "The temperature-rise limits given in Table 6 apply for …… and shall not be exceeded for ASSEMBLIES when verified in accordance with 10.10. …. The temperature rises obtained during the test shall not cause damage to current-carrying parts… " .

The referred Table 6 (see below) do not show objective values for connections of inner busbars an conductors as done in IEC documents above. There is no text presenting the grounds for the verifications that must be done,

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: – of metal – of insulating material	 15 [c] 25 [c]
Accessible external enclosures and covers: – metal surfaces – insulating surfaces	 30 [d] 40 [d]
Discrete arrangements of plug and socket-type connections	Determined by the limit for those components of the related equipment of which they form part [e]

The Notes under Table 6 are below.

a) The term "built-in components" means:

- conventional switchgear and controlgear;
- electronic sub-assemblies (e.g. rectifier bridge, printed circuit);
- parts of the equipment (e.g. regulator, stabilized power supply unit, operational amplifier).

b) The temperature-rise limit of 70 K is a value based on the conventional test of 10.10. An ASSEMBLY used or tested under installation conditions may have connections, the type, nature and disposition of which will not be the same as those adopted for the test, and a different temperature rise of terminals may result and may be required or accepted. Where the terminals of the built-in component are also the terminals for external insulated conductors, the lower of the corresponding temperature-rise limits shall be applied.

c) Manual operating means within ASSEMBLIES which are only accessible after the ASSEMBLY has been opened, for example draw-out handles which are operated infrequently, are allowed to assume a 25 K increase on these temperature-rise limits.

d) Unless otherwise specified, in the case of covers and enclosures, which are accessible but need not be touched during normal operation, a 10 K increase on these temperature-rise limits is permissible. External surfaces and parts over 2 m from the base of the ASSEMBLY are considered inaccessible.

e) This allows a degree of flexibility in respect of equipment (e.g. electronic devices) which is subject to temperature-rise limits different from those normally associated with switchgear and controlgear.

f) For temperature-rise tests according to 10.10 the temperature-rise limits have to be specified by the Original Manufacturer taking 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 conductors shall not be exceeded.

NOTE The 105 K relates to the temperature above which annealing of copper is likely to occur. Other materials may have a different maximum temperature rise.

By lack of information and mention to other values the “average reader” mentioned above is induced to understand that the temperature rise for the connections is 105 K and not other value as 50 or 85 or 75 K.
Days ago, I asked this question to 3 different low voltage cubicles manufacturers. All of them answered 105 K. It is difficult to know if this is due to the not clear text or if it is an interpretation leading to a more comfortable number.

It is well known that the critical point in temperature rise LV switchgear tests are the connections of the busbar to the circuit breakers (usually a bolted silvered connection). Possibly many people all over the world is considering as the limit the 105 K instead of 75K.

If you consider that for each 8 K above the temperature rise limit you have a loss of life of the contact around 50% the consequence of this extra 30 K is a very big reduction of lifetime. (see pages 94 to 115 in this book http://www.cognitor.com.br/Book_SE_SW_2013_ENG.pdf)

So, the question to the IEC 61439-1 standard makers is:
what is the limit of temperature rise to consider for a bolted / silvered connection between bus bars or between a busbar and a circuit breaker terminal? Is it 75K or 105K ?

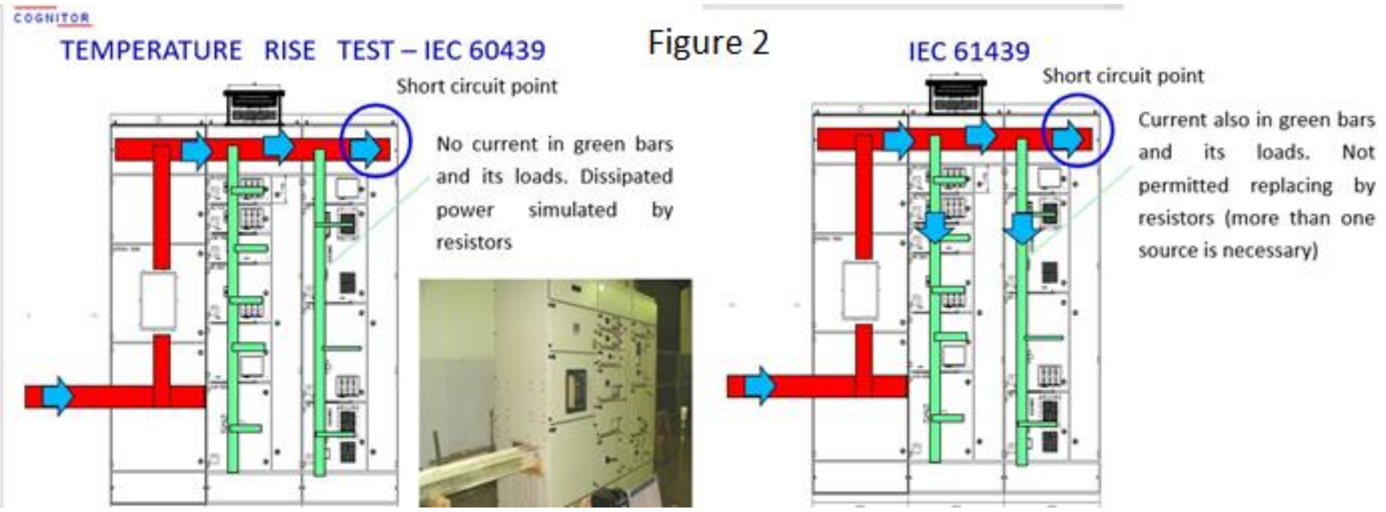
2.2- What is the number of current sources necessary to do the temperature rise test?

Months ago, a colleague from a big testing laboratory told me that the lab could do the tests in a LV switchboard according to IEC 60439 but could not do it according to IEC 61439-1. In the beginning I told him that he was wrong. However, when I went to read the details of IEC 61439 I could not understand the long and, at least for me, confusing text. Then I understood the doubt of my lab colleague. The doubt was not about the power available in the lab but, instead, about the number of sources necessary to do a test without an excessive duration. Excessive duration in labs means much higher prices of test. High prices of tests are not exactly a problem for a big manufacturer but can eliminate from the market medium and small manufacturers.

The main doubt is if the IEC 61439 added a test requirement much more complex than the previous IEC 60439. If I understood the writing of IEC 61439-1, the tests are now more difficult, more time consuming and expensive to do than before.

So, the questions to the IEC 61439-1 standard makers is:

a) Looking for the right side of the Figure 2 , how many current sources are necessary to do that test if the use of resistors is not permitted as it was in IEC 60439?
b) If the test methods are really different, should we re-test equipment already tested for IEC 60439 to be in accordance with IEC61439-1 ?



If I understood the text, the main difference between the standards is the possibility of using or not resistors to represent the effects of the power dissipation in the green bars (Figure 2). If you want to do a test more near the actual situation of use, as in IEC 61439, the onus of this sophistication, if compared with IEC 60439, is that it will be necessary to the laboratory to have several current sources to feed all bus bars. Allowing the placement of resistors to simulate the loads as in IEC 60439 will cause the temperature rise of the internal fluid. The effect will be transmitted (more or less well) to the hot spots as circuit breakers terminals, where the current is really circulating.

Adding extra requirements in IEC 61439 may be understood by users as the previous tests were incorrect. Possibly, this was not the purpose of the standard makers but is what is written there. Therefore, a clarification is needed in the next revisions. A possibility is to include in IEC 61439 explicitly, the possibility of replacing complicated tests by a simulation validated by comparison with existing test reports.

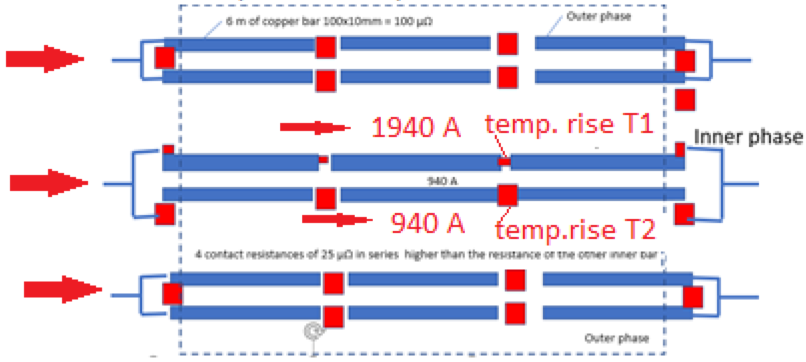
3 ARE TEMPERATURE RISE TESTS DONE WITH "WEAK" CURRENT SOURCES REPRODUCIBLE?

Recently a manufacturer of cubicles did a temperature rise test in a testing laboratory and got strange results and asked me to analyze what happened. They did a test in which some temperature rise values were measured and noticed that some points were much hotter than expected. Than they decided to put much more thermocouples than normally are done. The busbar was formed by something equivalent to having two 100x10 mm copper bars per phase.

The partial currents in the sub conductors were measured in each phase and – surprise - the currents, especially in the central phase, instead of being approximately equal had quite different values (see Figure 3). They were 1940 A and 940 A. The temperature rises T1 and T2 were coherent with these current values (90 K and 60 K)

Each sub-conductor of the 2x 100 x 10 mm copper bar has a calculated resistance of 100 microOhms a long the length of 6 m
Connections resistances not equilibrated by a factor 0f 4 x 25 microOhms

Figure 3



My first reaction was to say that some wrong measurement was made. However, after analyzing all the details I suspected about another reason for having these currents so unbalanced. If you are using a “weak” current source the applied voltage in the circuit is very small. The value of the sum of the connections resistances are of the order of the value of the electric resistance of the conductors. So, it is perfectly possible to have this unbalance. Looking to Figure 3, the blue sub conductor is a 6-meter-long copper 100x10 mm conductor.

The calculated resistance ($R=\rho \cdot L / S$) is 100 µΩ . Having a difference of connections resistances of 4 x 25 µΩ you will get the registered unbalance. The value 25 µΩ is something reasonable for the type of connections used. IEC 60943 shows the method to calculate.

Note that the geometry is perfectly symmetric and there are no steel supports in the busbar. So, other effects like skin effect and magnetic inductions could not cause this unbalance.

The reason why this effect is not observed in the regular lab tests is simple. No laboratory measures separately the currents in the sub conductors because the technical standard does not request this. It is also not common to place thermocouples in the two sub conductors at the same point (T1 and T2 in Figure 3) because we imagine that the temperature rises are approximately equal.

This case gives a strong indication that if you use a “weak” current source to feed a temperature rise tests and you measure just one of the sub conductor temperature rise you will not percept that this effect can occur.
In a real installation the source current is strong, and this effect will not occur.

If you can get, as in this case, a temperature rise of 90K or 60K in points which are very near this is not good because make the tests not reproducible. It is suggested to standards makers to investigate this point. Maybe some information should be added in the standards about this aspect.

4 FINAL COMMENTS

The purpose of this article was to present doubts of users about some requirements in IEC 61439-1 (Section2).

We also added a doubt about test reproducibility (Section 3).

Below there is one idea and a suggestion to IEC related to future work.

I hope these questions will reach the experts working in IEC WGs related to IEC 61439-1. Congratulations to them for including the "design rules" concepts. Would be great to extend this concept not only to short circuit tests.

I am posting this article in several Internet sites including the LinkedIn IEC The Electrotechnical Standards Group . I will also forward it to IEC.

When I receive responses, I will write an update of this article to make people know the answers. Usually IEC WGs reply such type of question. However, if actions are taken, they will appear years after in the next standard revisions.

I will use the opportunity of this article to send a suggestion to the IEC experts who prepare the documents about medium voltage and low voltage switchgear

> The only difference between a medium voltage cubicle or bus bar system or switchgear are the applied voltages. Simple like this. I wrote in some previous articles the idea that the texts for medium voltage and low voltage switchgear related to temperature rise, short circuits and electrodynamic forces, internal arc, IP, mechanical tests should be a unique (common clauses) and not different texts (one for low voltage committees and another one for medium voltage committees).
>
> The idea: It would be fantastic to have a future IEC publication named *"IEC xxxxx - Common specifications for medium & low voltage switchgear and controlgear"*. The text could be based in IEC 62271-1 & 307 and could call as reference the important and not very well-known documents like IEC 60943, IEC 60890, IEC 61117, IEC 60865. If IEC decides to do it, please call me to participate in the WG work and I will be there.

References:

[1] IEC 62271 – IEC 62271-1 High-voltage switchgear and controlgear – Part 1: Common Specifications
[2] IEC/TR 60943: Guidance concerning the permissible temperature rise for parts of electrical equipment,
[3] IEC/TR 60890: A Method of Temperature Rise Verification of LV Switchgear & Controlgear Assemblies by calculation.
[4] IEC 61117: Method for assessing the short-circuit withstand strength of partially type- tested assemblies (PTTA)
[5] IEC 60865 - 1: Short-circuit currents – calculation of effects - Part 1: Definitions and calculation
[6] IEC 60865 - 2: Short - circuit currents – calculation of effects – Part 2: Examples of calculation

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Some articles by Sergio can be freely downloaded in

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