Continuous Current Test on MV Switchgear and Controlgear: An Assessment in Respect of Contacts and Connections

S. Arjuna Rao[1(✉)], G. Girija[2], K. G. Rakesh[1(✉)], N. Maheswara Rao[2], B. R. V. Murthy[2], and S. K. Das[2]

[1] Heat Run Test Laboratory, Central Power Research Institute (CPRI), Bangalore, India
{sarjun,rakeshkg}@cpri.in
[2] Short Circuit Laboratory, Central Power Research Institute (CPRI), Bangalore, India

Abstract. The purpose of testing switchgear and controlgear assemblies is to access the product compliance interns of design aspects, materials used and manufacturing competency. The latest IEC 62271 series of standards reveals the test requirements and evaluation criteria to judge the performance of the equipment. This paper discloses key aspects of the continuous current test requirements, evaluation and interpretations on medium voltage switchgear components as per latest International Electrotechnical Commission (IEC) series of standards. During this study more than sixty-four medium voltage (MV) switchgear are considered for this analysis. The temperature rise values at the significant parts of medium voltage switchgear components with respect to applicable limits are used to judge the behaviour and life of contacts and connections.

Keywords: Continuous current · Breaker contacts · Temperature rise

1 Introduction

The Copper conductors can be used for operating temperatures up to 140 °C in par with series of standards dealing with low and high voltage switchgears. The composition and properties of aluminium and copper allows to use them as conductors in electrical equipment mainly switchgear and controlgear assemblies according to relevant IS, IEC & IEEE standards. Moreover, aluminium alloy conductors are preferably used due to their extensive mechanical properties which are much better than pure aluminium and also comparable with respect the copper. The Aluminium can also be used rapidly in several ranges of Electrical Industry as a substitute for the expensive copper as conductive material. But, the surfaces of both Copper & Aluminium conductor materials get oxidizes in normal ambient air. For consistent, harmless and long-standing steady electrical contacts, significant efforts are to be taken to keep with in permissible temperatures. Hence, to increase the contact behaviour of an electrical joint and also to reduce the assembly effort, the contact areas are often coated with materials like Tin (Sn), Silver (Ag) and Nickel (Ni). Particularly on aluminium bus bar surfaces, a hard

© The Author(s) 2023
B. Raj et al. (Eds.): ICETE 2023, AER 223, pp. 625–637, 2023.
https://doi.org/10.2991/978-94-6463-252-1_64

and dense oxide layer, which is electrically insulating in nature at thickness of a few nanometres, may get formed within short duration itself, due to the oxidation in atmospheric conditions [2]. According to IEC 62271–1:2017, the absolute temperature value for contacts and connections with Silver or Nickel coated in Oxidizing gas or Not Oxidizing gas (NOG) is 115 °C. The same value can have observed even for bare copper or copper alloy contacts and connections in NOG medium [1]. For the case of Tin coated, the absolute temperature is limited 90 °C for contacts and 105 °C for connections for both OG and NOG mediums respectively. The most commonly used NOG is Sulphur Hexafluoride (SF6) because of its high dielectric strength, inflammable and chemically stable characteristics.

1.1 Objective

Generally, high voltage is defined as the voltage above 1000 V for any equipment whereas, the medium voltage in distribution system is with the voltage above 1000 V and up to and including 52 kV. CPRI has been dealing with several Type and Routine tests applicable to the MV/HV switchgear assemblies. In present paper continuous current test importance on a medium voltage switchgear assembly is considered to evaluate the temperature rise at various parts. In other words, sub-clause 7.5 of IEC 62271–1 standard is referred to conduct this test on medium voltage (MV) switchgear and controlgear assembly [7]. The assessment is done through the temperature rise test as per IEC standards, conducted on various ratings of MV switchgear assembly and the readings are measured, compared and analysed. An increase in the temperature rise limit in latest IEC is justified with respect to the thermocouple positions and dissipation of heat [8].

2 Coating of Contacts in Switchgear

In the transmission, the conductors are generally made up of copper or Aluminium. But on the surface of these materials an insulating oxide layer develops during its long run in ambient air. To overcome this issue, contact surfaces generally at joints using these materials of Aluminium or copper are coated with silver, nickel or tin. The high voltage switchgear standard, IEC 62271–1:2017 deals about the permissible limits applicable with respect the material coatings [1]. We can able to draw out substantial changes with reference limits applicable compared with old IEC 62271–1:2011 standard is concerned.

2.1 Silver, Tin & Nickel Coatings

Apart from other factors of relevance, the quality of an electrical contact rests on the physical parameters of the coating material that are indicated in Table 1. The significant material properties with a high conductivity are:

- Surface roughness
- Conductivity of coating
- Contact force
- Mechanical properties of contact materials

Table 1. Physical properties of different coatings

Parameters	Value		
	Sliver (Ag)	Tin (Sn)	Nicke l(Ni)
Density **'δ'-**g/cm^3	10.49	5.77	8.907
Melting point 'T_{melt}'-°C	960.5	232	1454
Softening temperature 'Tsoft'-°C	150	138	370
Vickers hardness-HV	28–100	50–440	110–170
Tensile strength 'R_z'-N/mm^2	190–380	200–220	370–700
Modules of elasticity 'E' (Young's modulus) -kN/mm^2	79	251	216
Temperature co-efficient of Resistance 'α_T'-$10^{-3}K^{-1}$	4.1	11.0	6.75

a) Young's modulus
b) Hardness

Silver coating has been established as one of the finest coating material became of its superior electrical conductivity and resistance to the formation of oxide layer at the existing ambient conditions. Nickel also can be coated directly on the commonly used metals in electrical products. With sufficient thickness and tightness, it works very effective as a diffusion barrier. The price of Nickel is much lower compared with silver, which aims to focus on research to study the long term behaviour of nickel coated contacts or joints [2]. The study can also aim towards long term analysis between the nickel coated bolted joints versus silver coated bolted joints on bus bars made up of copper or Aluminium at higher ambient temperatures. The metal-enclosed switchgear and applicable circuit breakers engaged with switchgear assemblies describe the temperature rise limits for several parts of the product [3]. Usually, the temperature rise allowable is significantly higher for plated connections and contacts than that of un-plated connections or joints. The coating of silver is used, particularly for sliding contacts in switchgear. The reason for that is silver plating will be tougher than tin plating and resists the stresses develop at moving joints, like as hinge point or crucial disconnect which found to better than tin plating. Nevertheless, the Tin plating is also greater in definite industrial conditions and atmospheres, such as those containing hydrogen sulphide [2]. Currently, Tin (Sn) plating is identified as a potential alternate to silver plating in MV/HV Circuit breakers due to cost effective in nature and other advantages. The substrate material for the terminals, contacts and connections such as joints will be of copper alloy. In this paper, the temperature rise results were analysed with respect to tin and silver coatings on contacts for both tulip and finger contacts. The variations in temperature rise in respect of number of fingers in contact section is analysed.

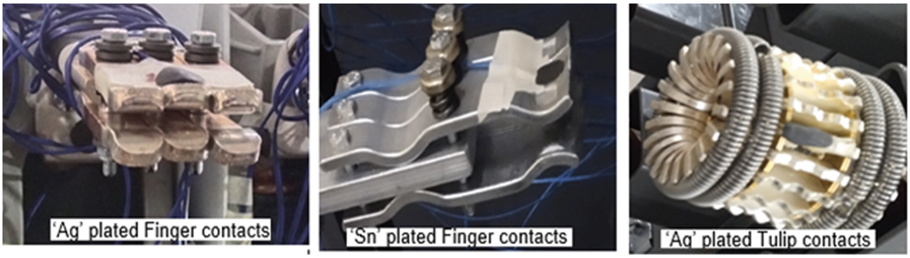


Fig. 1. Different types of contacts in the breaker compartments of MV switchgear

3 Breaker Engaging Contacts in Switchgear

In IEC 62271–1:2017, the limit for un-plated copper contacts is 35 °C above the ambient temperature not exceeding 40 °C, while the limit for silver coated contacts is 75 °C which is much higher compared to former [1]. The temperature rise permissible is more for plated contacts or connections. The reason is plated copper does not oxidize as swiftly as that of bare copper. Copper oxide is not a good conductor [4]. As the oxide film get forms above the surface material, the resistance and the temperature rise of the connections and conductor get increases quickly. Subsequently limiting the temperature rise only to 35 °C will become difficult and demands the manufacturers to use double the amount of copper. Hence the contacts, connections with joints are almost generally plated. Due to numerous practical and manufacturing causes, it is no more recommended to standby tin for silver to the surfaces inside circuit breakers primary disengage portions. To overcome the effects due to atmospheric conditions silver coated contacts/ surfaces shall be coated with connection lubricating grease to avoid corrosion difficulties [4]. Different types of contact uncouple portions are shown in Fig. 1 such as Silver (Ag) and Tin (Sn) coatings.

3.1 Tulip Type Contacts

Commonly, the tulip contact includes a number of inner connection fingers and outer connection fingers. Altogether the contact fingers include a first contact bulge for get in touch with the shells of the fixed contact, and additional contact bulge for contacting with the bushing. Each connection bulge includes a contact slot on its external surface. The main connection knots of the outside connection fingers are not at the same area of cross section with the main connection knots of the internal connection fingers.

3.2 Finger and Wedge Contacts

This series of primary moving contacts also known as tension spring-type flat contacts and used in high-voltage switchgear panels. They are the core conductive switching elements in high-voltage switching devices. These contacts can be used up to the rated working voltage of 36 kV with 2500A. Contacts are the main conductive portions of switchgear and their reliability directly affects the consistent procedure of the entire network of power system.

3.3 BUTT Contacts

Whereas, the other contacts are of ‘BUTT’ type contacts meaning that the main contacts make flat against each other when the breaker is closed. The butt contact can flexibly track the uneven surface of a contact point and enables a long-lasting and stable electrical connection. The butt type contact and is formed by the springs. Can handle current up to the range of 2000A [3].

4 Continuous Current Test

Before analysing the effects coatings on the contacts and connections, it is worth to understand the methodology behind the continuous current test. The continuous Current Test is previously known as Temperature – Rise test as per relevant IEC 62271 series of Standards. The switchgear may consist of main and auxiliary circuits. As per IEC 62271–200:2021, main circuit in the panel or assembly is considered for the test, assuming the auxiliary circuits are verified during the mechanical endurance tests. The contact in the switchgear shall be in clean and operable condition with minimum contact resistance during close and open operations. Wherever, it is applicable the liquid (oil) or gas (such as SF6) shall be filled with minimal functional pressure before performing the continuous current test. The indoor environment where the test is proposed to conduct must be free from air currents. This conditions achievable where the value of air velocity shall not exceed the value of 0.5 m/s. When we test the switchgear as per industrialist’s instructions, the sample can be allowed to get installed in dissimilar positions. The continuous current test shall be performed mounting the test object in most unfavourable condition to check the severity. Generally, the test will be made on the three pole switchgear itself energising all the poles with the suitable high current and low voltage source. This can be permitted to take up on distinct pole or on a distinct unit provided the effect of the other adjacent poles or unit is considered to be insignificant. For the three pole switchgear of rated continuous current value not more than 1250A, the test can be taken up by connecting all poles in series while feeding the test current.

4.1 Test Current and Duration

In order to make the continuous current test extra effective, the nature and size of conductors can be detailed in the relevant product standard. Generally, the test will be performed on the main circuit with the rated continuous current until the steady state condition’s established. The test current is assumed to sinusoidal in nature free from Harmonics. This requirement can be attained when the RMS value of the harmonics content does exceed the value of 5% of the functional value. The supply frequency of the test current shall be of the tolerance between +2% to 5%. The test will be continued until the stable condition is achieved. This situation is considered to be attained when the variation of the temperature rise at the respective points of measurement shall not exceed 1K per one hour [8]. The variation in temperature rise according to IEC standard is measured and intended by using the underneath equation:

$$\Delta\theta = \mathrm{T(t)} - \mathrm{T(t - 1\,h)} \quad (1)$$

whereas T (t) is the value of temperature measured at the definite hour, while

T (t − 1 h) is the value temperature measured before an hour.

The preheating is permitted with higher value for a short period in order to shorten the duration of the test. If the switchgear consists with multiple functional units, each functional unit need to be tested once at its rated current value meanwhile keep the adjacent functional unit loaded respectively or simulating the heating condition with heater get installed in the cabins. The details of temporary bus bars, instruments used and breaker temperature rise values shall be reported in the test reports to check with the compliance [9, 10].

4.2 Temperature Measurements During Test

4.2.1 Ambient Temperature Measurement

The value of ambient air temperature must be in between 10 °C to 40 °C. This temperature is nothing but temperature of air neighbouring the test sample. It must be measured by keeping minimum three numbers of thermometers or thermocouples positioned in vicinity of the sample under test. The temperature measuring devices must be distributed around the test object at half of the height and at a distance of 1m from the test sample. The thermometers or thermocouples used shall be placed in small bottles comprising of about 0.5 L of oil [1]. The main purpose of using oil is due to the nature of high viscosity and computing errors due to free air turbulences can be nullified.

4.2.2 Test Object Temperature

The method of measuring temperature rise for the coils shall be through variation of resistance. The other method is by the use of thermocouples or thermometers only if it is unworkable to practice resistance method. The resistive device of suitable type such as T type, K Type or J type thermocouples need to place at the hottest accessible points. The thermocouple works on the principle of Seebeck effect and more accurate in prediction of temperature at respective points. The common sources of generating heat in switchgear assembly are listed in Table 2. The temperatures at the contacts, connections, terminals and insulating materials needs to be measured periodically by using data acquisition system such as data loggers with high accuracy. The temperature rise at the terminals of the main circuit and at a space of 1m on the temporary test conductor from the terminals needs to be measured during the test. This gives the index about the appropriate usage of temporary conductor which may act as heat sources or heat sinks. The difference the temperature rises measured in above context between terminals and 1m away on temporary conductor shall not exceed 5K. By chance if it exceeds by 5k also, the test will be considered as valid if all the criteria to pass the test met with respect to the limits that were listed out in IEC 62271–1:2017.

5 Interpretation of Continuous Current Test (Temperature-Rise)

The latest IEC – 62271 series of standards give the details about the changes in the Temperature rise limits that are applicable to HV/MV switchgear and controlgear. In continuous current tests on switchgear assemblies, the point at which the temperature

Table 2. Sources of Heat Generation in Switchgear

Heat sources	Power circuits	Control and auxiliary circuits
• **Heat generated by resistance loss** • **Dielectric loss** • **Eddy current loss**	• Interrupting devices such as breakers, power contactors, switches, fuses and MCCBs • Thermal elements and contacts belongs to over-load relays • Power contacts of incoming and outgoing circuits	• Power contactors coils • Coils belongs to auxiliary contactors such as relays • Coils of timers circuits • Control fuses and fuse links

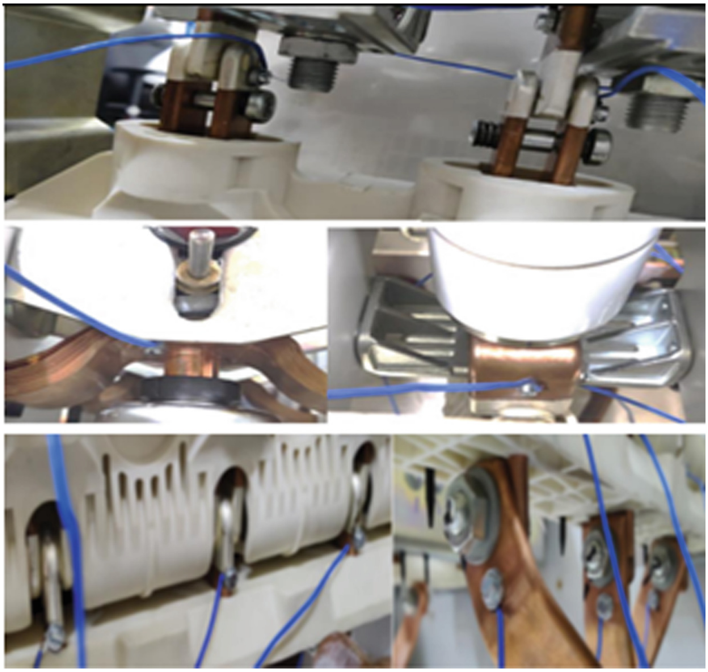
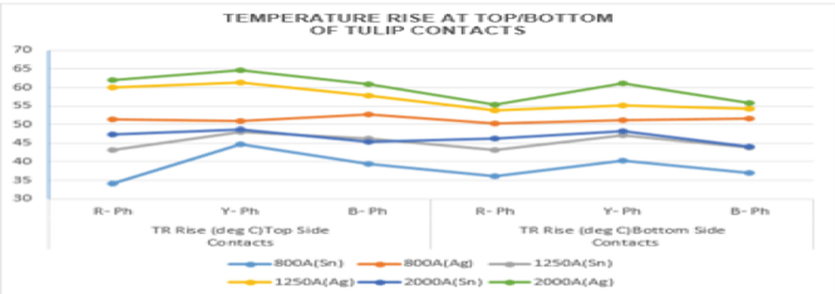


Fig. 2. Thermocouples at crucial spots in Switchgear assembly (Courtesy: M/s.ABB India Ltd.)

being measured is very important in evaluating the concert of item or equipment under test. The objective of continuous current test to check the temperature-rise at the critical areas such as contacts, connections bolted or equivalent and terminals that being connected with the external conductors by screws or bolts (Fig. 2).

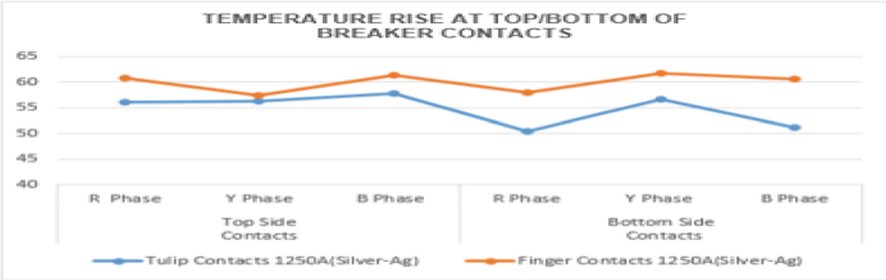
5.1 Analysis of Temperature Rise at Contacts

As a part analysing effects of coatings on breaker contacts, several 12kV & 36kV breakers in MV switchgear panels are studied with reference to the temperature rise tests that were carried out in laboratory and respective test results. Generally, there are three types of contacts at the engaging portions of the breakers in switchgears such as Tulip contacts, Finger contacts and Butt contacts. The usage of a tulip contact assemblage for the electrical joining of a detachable conducting terminal, if on a draw-out medium voltage circuit breaker, to a standing conducting terminals of the switchgear component. The Temperature rise values at silver (Ag) coated contacts and Tin (Sn) coated contacts of Vacuum Circuit Breaker (VCB) for the rating of 12kV are tabulated and analysed in Fig. 3. The value of temperature rise limit for the Silver coated contacts is 75 °C whereas, the limit for Tin coated contacts is 50 °C as per the relevant IEC 62271–1:2017 standard. The type of contacts also plays a vital role in affecting the temperature rise results. Hence, for 36kV breaker rating the temperature rise variations with reference to Tulip contacts and Finger contacts assemblies are also analysed and tabulated. The Tulip contacts at the breaker engaging portions is always exhibits certain advantage over finger contact assembly. The contacts can be of multiple fingers to keep the contacts quite intact and steady. The tulip contacts may possess multiple parallel sections with the end rings. The butt contact assemblies are very less to get use with VCBs in MV switchgear and controlgear but cab used very widely in oil circuit breakers with high current ratings. The analysis with respect to Tulip versus Finger contacts is shown in Fig. 4. The use of finger contacts as demountable in switchgear assemblies also significant. The number of fingers may vary with reference to the rating of the breaker. The coating of the contacts can be of 'Sn' plated or 'Ag' plated. The temperature rise values with respect to number of fingers has been analysed and shown in the Fig. 5 for the 12kV switchgear assembly.



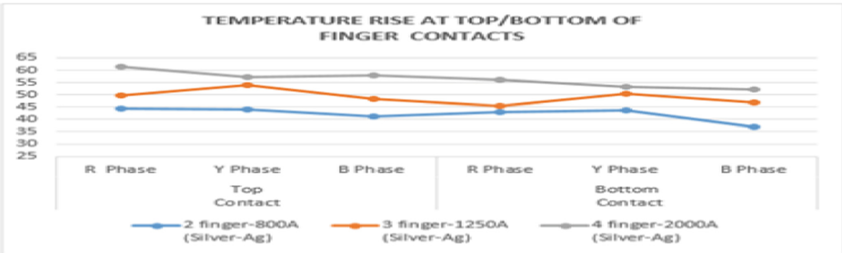
Current rating/ Plating	Temperature Rise-°C					
	Top Side Contacts			Bottom Side Contacts		
	R Phase	Y Phase	B Phase	R Phase	Y Phase	B Phase
800A(Sn)	34.1	44.7	39.4	36.2	40.4	37.1
800A(Ag)	51.4	50.9	52.8	50.3	51.2	51.6
1250A(Sn)	43.2	48.1	46.2	43.1	47.1	43.9
1250A(Ag)	60.1	61.3	57.8	53.8	55.1	54.3
2000A(Sn)	47.3	48.8	45.5	46.4	48.2	44.1
2000A(Ag)	62.1	64.7	61.0	55.3	61.1	55.9
Voltage class of the breaker-12 kV						

Fig. 3. Temperature rise at top and bottom engaging contacts in Breaker Assembly



Current rating/Plating	Temperature Rise-°C					
	Top Side Contacts			Bottom Side Contacts		
	R Phase	Y Phase	B Phase	R Phase	Y Phase	B Phase
1250A(Ag)- Tulip	56.1	56.3	57.8	50.5	56.7	51.1
1250A(Ag)- Finger	60.8	57.4	61.4	57.9	61.7	60.6
Voltage class of the breaker-36 kV						

Fig. 4. Temperature rise in Tulip/Finger contacts in Breaker Assembly



Current rating/No. of Fingers	Temperature Rise-°C					
	Top Side Contacts			Bottom Side Contacts		
	R Phase	Y Phase	B Phase	R Phase	Y Phase	B Phase
2 finger-800A (Silver-Ag)	44.3	44	41.2	42.9	43.6	36.9
3 finger-1250A (Silver-Ag)	49.6	53.9	48.3	45.6	50.6	46.8
4 finger-2000A (Silver-Ag)	61.3	57.2	57.8	56.2	53.3	52.6
Voltage class of the breaker-12 kV						

Fig. 5. Temperature rise in Finger contacts in Breaker Assembly

5.2 Contact Materials, Connections & Terminals

The nature of materials that being used at the decisive locations needs to be analysed before drawing the temperature rise limits. The so called crucial points (parts) are made up of bare copper / bare copper alloy, Silver coated, Nickel / Tin-coated. When engaging

Table 3. Temperature-rise limits comparison between New Vs Old Standards in switchgear assembly [1, 6]

Nature of the part, of the material	Maximum value				
	Temperature Rise in °C (at ambient ≤ 40 °C)				
	IEC 62271-1:2017		IEC 62271-1:2011		Interpretations
Contacts	Bare Copper / bare-Copper alloy				
	In OG	75	35	75	35	For bare, limits are slightly liberal for NOG in latest IEC
	In NOG	115	75	105	65	
	In oil	80	40	80	40	
	Silver coated / Nickel-coated					
	In OG	115	75	105	65	For 'Ag'/ Ni coatings, limits are slightly liberal for both OG & NOG in latest IEC
	In NOG	115	75	105	65	
	In oil	90	50	90	50	
	Tin coated					
	In OG	90	50	90	50	For Tin(Sn) coating, no specific changes in limits
	In NOG	90	50	90	50	
	In oil	90	50	90	50	
Connection, (Bolted or the equivalent)	Bare Copper, bare Copper alloy / bare-Aluminium alloy					
	In OG	100	60	90	50	For the bare, limits are slightly liberal for OG in latest IEC
	In NOG	115	75	115	75	
	In oil	100	60	100	60	
	Silver coated / Nickel coated					
	In OG	115	75	115	75	For 'Ag'/ Ni coatings, no specific changes in limits

(*continued*)

parts in exclusive are having different coatings on the material which is bare the criteria of allowable temperatures and respective rise(s) should be considered as follows.

- *For contacts:* Those of the external surface material having the lowermost value permitted in the Table 3.

  This contacts includes an extensive range of bolted or crimped type. The clamped joint evades the saving in cross section produced by puncturing to insert bolts and gives even distribution of the contact force. This makes the contact more effective and keeps calm [5]. Bolting is preferable because it is cost effective and convenient.
- *For connections such as bolted or equivalent:*

Table 3. (*continued*)

Nature of the part, of the material	Maximum value					
	Temperature Rise in °C (at ambient ≤ 40 °C)					
	IEC 62271-1:2017			IEC 62271-1:2011		Interpretations
	In NOG	115	75	115	75	
	In oil	100	60	100	60	
	Tin-coated					
	In OG	105	65	105	65	For Tin(Sn) coating , no specific changes in limits
	In NOG	105	65	105	65	
	In oil	100	60	100	60	
Terminals for the external conductors	Bare	100	60	90	50	For both bare & Ag/ Ni coated, limits are slightly liberal in latest IEC
	Silver /Nickel coated	115	75	105	65	
	Tin coated	105	65	105	65	

Those of the external surface material partaking the highest value permitted in Table 3 given from IEC 62271–1:2017. Generally, crimped joints pay the great force of contact creation, producing to make an enduring joining. The easy nature of these joints, and the ease and rapidity of the crimping makes this type of joint very attractive for stable connections [5].

5.3 Insulating Medium in Switchgear

The temperature limits that were applicable to the switchgear assembles are mainly get influenced with respect the insulating materials being used as cooling agents, As per the new IEC standards are concerned, they presented the difference of parts in 'Oxidizing (OG)' and 'Not oxidizing gas (NOG)' replacing the previous "Air" and "Sf_6".The Not oxidizing gases for the purposes of this particular IEC 62271 standard are that of non-reactive gases that are measured as non-accelerating ageing behaviour of contacts by corrosion or oxidation because of inherent chemical configuration and characteristics. Similarly, oxidizing gases are relative gases that can accelerate ageing of contacts both by corrosion occurrences mostly due to the ambient air medium alike oxygen. Gases classified under OG are ambient air,'dry' air any gas that was not categorised as NOG [1]. The heat distribution at crucial joints can be analysed further by the latest techniques like Thermography, FEA and CFD based simulation methods [11].

6 Conclusion

This technical paper mainly discussed and reviewed the key technical aspects that affects the results of temperature rise at the vital points of measurement relevant to MV/HV switchgear panels and circuit breakers. The new limits that were applicable to Contacts, Connections & Terminals are discussed as per the latest IEC standards. The significant use of temporary test conductors during Temperature rise test is emphasized the escalation in Temperature rise is because of various causes such as current density of materials, design, workmanship & contact pressure. The excess temperature rise outcomes in loss of energy and also damaging to the parts like insulation which leads to the failing of the related switching mechanisms and breakers. The scheme must be monitoring the heat transfer behaviour periodically inside the medium or high voltage switchgear compartment provides the enhanced indulgent about the flow of temperature distribution.

Acknowledgements. The authors of the paper are very much grateful to the management of Central Power Research Institute (CPRI), India for the backup and support of this study.

References

1. IEC 62271–1:2017, High-voltage switchgear and controlgear – Part 1: Common specifications for alternating current switchgear and control gear.
2. M. Braunovic, "Electrical contacts: Fundamentals, applications and technology", CRC Press, 2007, ISBN 978-1-57444-727-9
3. X. Wang et al., "Research on temperature rise of high current switchgear in distribution system," in The Journal of Engineering, vol. 2019, no. 16, pp. 2931–2934, 3 2019.
4. Yuan. S, Xiaodong. C, Tianxiang. C "Analysis and estimation of temperature rise of medium voltage switchgear cabin" J. *Xiamen Univ. Technol*., 2015, 23, (1), pp 45–50.
5. https://electricenergyonline.com/energy/magazine/306/article/Electrical-contacts-in-MV-HV-Power-Circuit-breakers.htm.
6. IEC 62271–1:2011, High-voltage switchgear and control gear – Part 1: Common specifications.
7. Fjeld, E., Rondeel, W.G.J., Attar, E., Singh, S.: Estimate the temperature rise of medium voltage metal enclosed switchgear by simplified heat transfer calculations. IEEE Trans. Power Delivery 36, 853–860 (2021).
8. Wang, L., Zheng, W., Wang, L., Lin, J., Li, X., Jia, S.: Electromagnetic thermal-flow field coupling simulation of 12-kV medium-voltage switchgear. IEEE Trans. Compon. Packag. Manuf. Technol. 6, 1208–1220 (2016)
9. Szulborski, M., Łapczynski, S., Kolimas, Ł.: Thermal analysis of heat distribution in bus bars during rated current flow in low-voltage industrial switchgear. Energies 14, 2427 (2021).
10. Iderus, S., Peter, G.: Temperature rise test on medium voltage switchgear assembly based on IEC standard. In: 2020 8th International Conference on Orange Technology (ICOT). Daegu, Korea (South), pp. 1–5 (2020).
11. Zhao, Y., Chen, L., Qiao, R.: Temperature field simulation and structure improvement of 12 kV switchgear. J. Phys.: Conf. Ser. 2179(1), 012010 (2022).

Open Access This chapter is licensed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (http://creativecommons.org/licenses/by-nc/4.0/), which permits any noncommercial use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.