NAME : GREGOIRE
COUNTRY : FRANCE
REGISTRATION NUMBER : **DLG5186**

GROUP REF. : A3
PREF. SUBJECT : PS2
QUESTION N° : Q9

Question :

There are conflicting reports on temperature rise performance of SF6 alternatives. Report 10658 reports an issue, 10657 reports high values at 2500 A whereas authors of 10126 show results like SF_6. Can specialists shed some light on the various influential factors and how they are controlled?

Answer:

Temperature rise performance in high voltage switchgear is driven by several parameters. International standards define temperature rise limits for various type of material and type of connections.

The temperature rise of an apparatus is the result of the competition between the heat source (power loss generated by the main circuit resistance and the nominal current) and the heat transfer capability to drain the heat out of the switchgear).

Solutions allowing to replace SF_6 in high voltage equipment are generally realized using natural origin gas with the addition of synthetic molecule C4FN in limited amount (≤ 6%).
These gases have been studied to determine their heat transfer capabilities compared with SF_6.

1)Impact of the insulating gas on temperature rise:

To study the impact of the insulating gas, a simple theoretical approach can be obtained by calculating the thermal effusivity of the gas. In thermodynamics, a material's thermal effusivity, thermal inertia or thermal responsivity is a measure of its ability to exchange thermal energy with its surroundings.

$$e = \sqrt{k.\rho.C_p}$$

with e : thermal effusivity [J/m² K s$^{0.5}$]
k : thermal conductivity [W/(m K)]
ρ: density [kg/m³]
C_p : specific heat capacity [J/(kg K)]

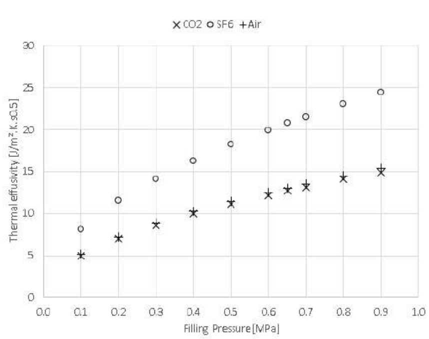

Figure 1: Thermal effusivity of CO2, SF6 and technical air

When comparing for example CO_2 or technical air with SF_6, it is found that the thermal effusivity of the natural origin gas is lower than SF_6. Alternatives to SF_6 are generally designed to operate at higher filling pressure than SF6. Therefore, as seen on figure 1, the loss due to the gas change is already partly compensated with the pressure increase. Nevertheless, in real equipment, an increase of 10 to 15% in temperature rise can be observed on a same test object only changing the gas and adapting the pressure scale. This gap was confirmed in several type of HV equipment including GIS bus bar, Live Tank and Dead Tank.

[1] lead theoretical, numerical, and real test comparison and confirmed the temperature rise increase between CO_2 / O_2, technical air and SF_6. The addition of C4FN in the mixture enhances the thermal effusivity as the temperature rise performance was improved with the C4FN/O_2/CO_2 mixture (figure 3).

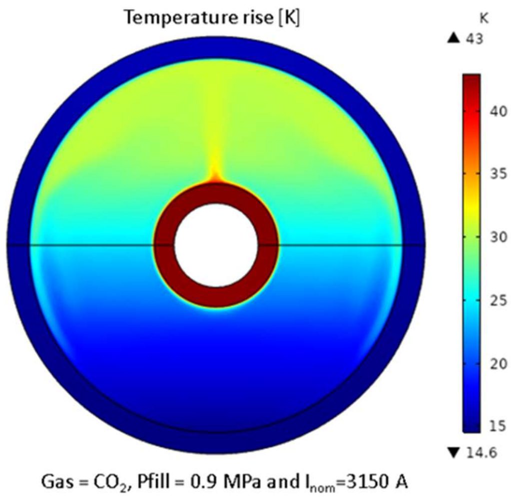

Figure 3: bus bar temperature rise simulation

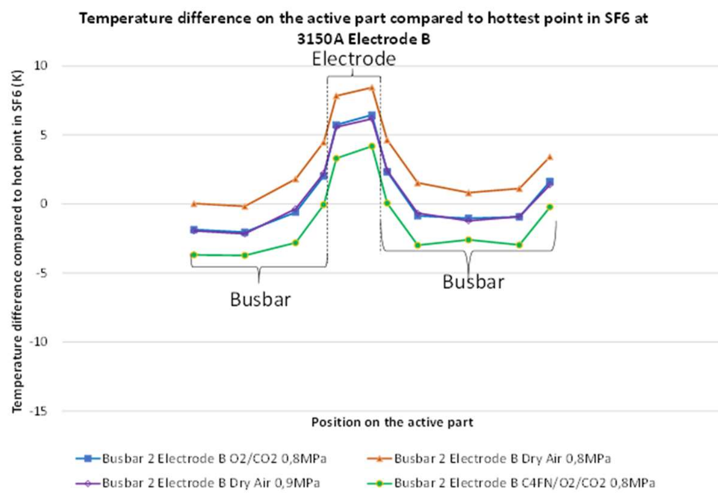

Figure 2: Temperature rise test results on GIS bus bar

1)Influential factors on temperature rise performance:

To keep the same footprint and same nominal current performance with C4FN/O_2/CO_2 mixture as the existing SF6 equipment, various influential factors have been used to overcome this increase of temperature:

- Filling pressure

The filling pressure is key in determining the ability to dissipate heat. If higher pressure can be accommodated (pressure vessel design, dielectric withstand, standards… can be severely impacted), a gain on temperature rise should be granted.

- Conductor design and material

Conductor design is key. They are generating most of the heat from their material resistivity. Therefore, using low resistivity material (Copper versus Aluminium) allows to reduce the overall resistance and therefore to limit the heat generated through joule losses.
Conduction design (shape, surface…) is also key as it will determine heat flux exchanged with the surrounding gas. Radiative, convective mainly but also conductive heat transfer will be established, therefore conductor design is key to limit temperature rise.

- Contact design

Contacts are generally representing an important local source of heat. Because of the imperfect contacts, this local area generally represents hot spots which may limit the temperature rise. Contact design optimization or number is key to avoid local high temperature rise.

- Margin in SF_6 and standard

Some SF_6 switchgear may have temperature margin compared to the standard allowance. This margin may be sufficient to reuse the same design with an alternative gas to SF6. Also, recently ([2] in 2017) standards have increased the temperature limits allowed on contacts and terminals. This increase is generally sufficient to cover the increase in temperature rise switching from SF_6 to $C4FN/O_2/CO_2$

References

[1] Victor Hermosillo et Al. - Comparative Continuous and Overload Current Performance of High Voltage Switchgear with SF6 and Alternative Gases, A3_PS2_10126_CIGRE 2022
[2] IEC 62271-1 - Edition 2.0 2017-07 - High-voltage switchgear and controlgear –Part 1: Common specifications for alternating current switchgear and controlgear.