NAME : OZIL / GREGOIRE/ BERTELOOT
COUNTRY : FR
REGISTRATION NUMBER :

GROUP REF. : D1 SF6-free
PREF. SUBJECT : PS2
QUESTION N° : Q2.03

Q2-03

Decomposition of gases may have substantial impact on the long-term performance of gas-insulated systems. Low-GWP gases may be of lower stability compared to SF6. Is there any experience concerning decomposition of low-GWP gases available? How should this aspect be tested to ensure reliability in the long-term range?

Answer

The C4-FN gas mixture, where C4-FN is mixed with CO_2 & O_2, is the most efficient SF6 alternative solution for the full High voltage switchgear range with very low-GWP and the best environmental impact confirmed by Life Cycle Assessment (LCA) [1], [2].

The stability of this gas mixture and the reliability of the equipment using this gas are continuously studied and monitored.

Long term behaviour of the SF6-free gas depends on potential gas composition variation. Several parameters could be considered as the:

- Gas composition variation due to switching and interruption of short-circuit current;
- Gas mixture homogenisation under gravity in the long term;
- Gas composition monitoring in outdoor conditions;
- Real equipment at site energised since 2018.

1/ Gas composition due to switching

Gas mixture composition will change when part of the gas species initially present in the gas mixture will not recombine after arcing. For example, C4-FN will dissociate into other species, which will lead to a modification of the dielectric withstand.

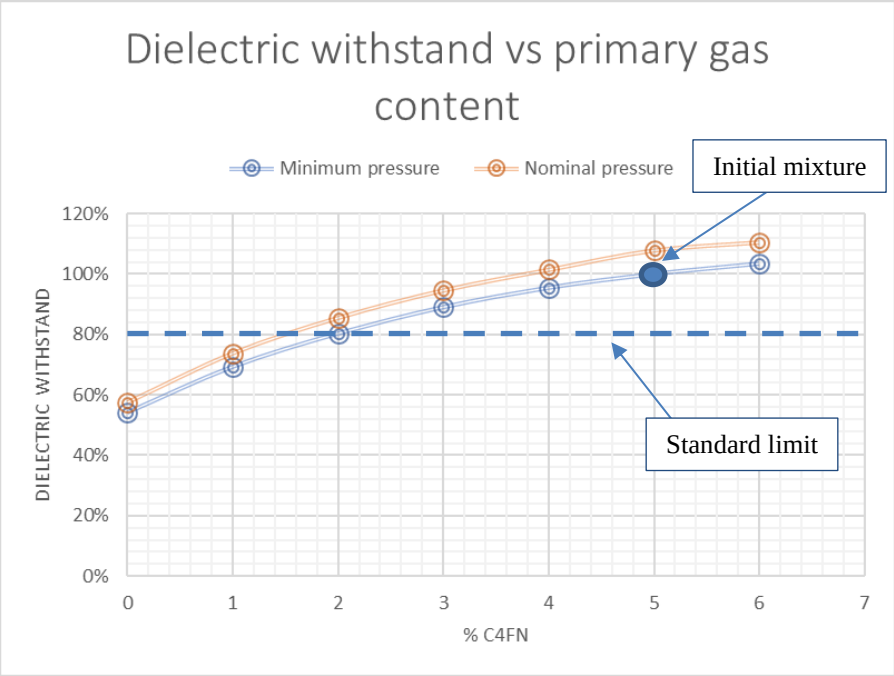

Figure 1: dielectric withstand vs primary gas (C4FN) content

The reported C4-FN consumption would generally not lead to a dielectric withstand reduction higher than 10% at the end of the lifetime [2], [3].

In [2] and [3], the dielectric withstand at the end of electrical lifetime is remaining much higher than the standardised voltage condition check values indicating that the limit of electrical lifetime is reached first, as in SF_6, on the arcing contacts and PTFE parts.

This conclusion is also described in CIGRE Technical Brochure 871 [4] (see Figure 2) which explains that in the range of practical use of the C4-FN gas mixture, the variation of C4-FN content has a minor impact on the dielectric withstand.

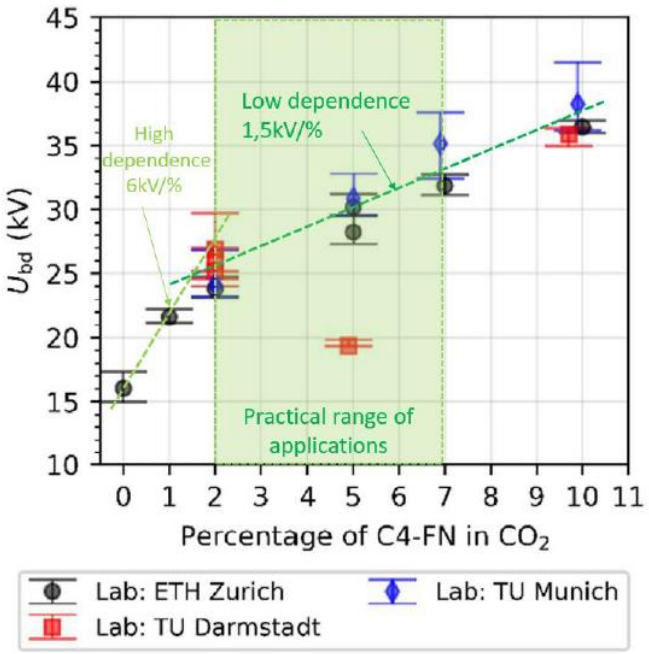

Figure 2: Dielectric withstand levels against C4-FN content

2/ The mixture homogeneity overtime under gravity

As the molar mass of C4-FN is much above the one of CO_2, O_2 and N_2 (ex: C4-FN=4,5 times CO_2), we must ensure that the gas remains homogeneous.

As described in literature for SF_6/N_2 mixtures, the impact of the height appears for gas compartments' heights above 20 m, which is much more than most gas compartments for high voltage products.

To investigate this phenomenon in the long term, a simple cylindrical gas volume was setup using standard aluminium housings used for GIS. The complete assembly was 4344 mm high and included four standard gas ports. The test object was placed outside for the long-term investigation in Villeurbanne, France, as shown in Figure 3.

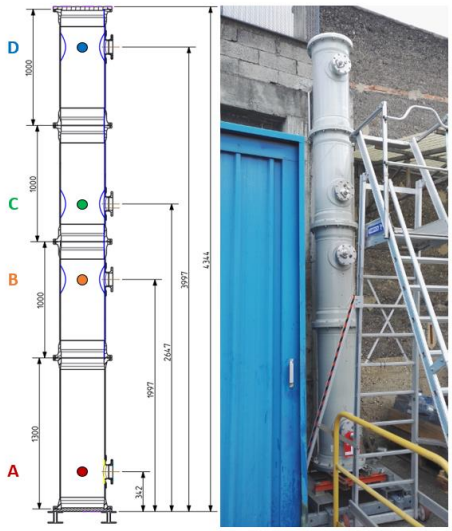

Figure 3 - Experimental setup to investigate effect of gravity

The measures were taken on the four gas ports over almost three years from 2019 to 2022 (Fig. 3). The measured C4-FN values are presented in Figure 4. A minor scattering of the data is visible and appears to be linked to the measurement tolerances and not a real variation of concentration over the test duration. This is a clear indicator that segregation due to gravity does not exist.

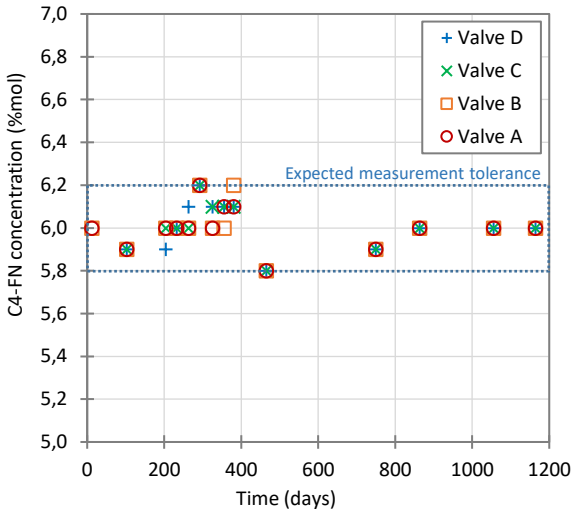

Figure 4 - C4-FN evolution over three years measured at each port by mobile analyzers

Results show that the C4-FN content is the same at all measurement points.

3/ Gas composition evolution in outdoor conditions

Long term ageing tests with a voltage transformer was performed in the outdoor test field on a functional 145 kV inductive voltage transformer (VT), which was filled with a C4-FN mixture. The VT was reversely fed through its power coil 1 to operate at a voltage of 1.25 U_n, i.e., 180 kV phase-to-phase and 104 kV phase-to-earth. The applied voltage was measured by the VT measuring coil 2.

A simplified representation of the test setup is given by Figure 5 and shows the VT and two additional gas volumes.

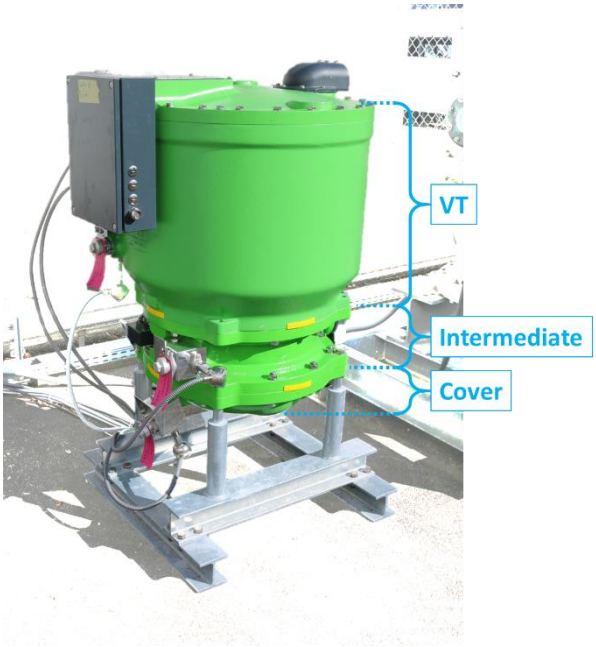

Figure 5 - VT setup used for long term tests between 2015 and 2021

Starting in February 2015, the VT was maintained under test voltage for more than 800 days. No breakdown or abnormal activity occurred.

In May 2017 the VT was moved from the outdoor test field to the high voltage laboratory and passed a 60 Hz AC, 235 kV, 1 min test. No PD activity was detected, neither at the 174 kV level nor at 235 kV.

At VT inspection, some minor by-products from C4-FN hydrolysis were observed during both ageing tests. C4-FN hydrolysis is a chemical reaction between C4-FN and H2O. It leads to minor production of gaseous and solid by-products. The amount is very limited thanks to the limited amount of humidity in the product.
Both long term ageing tests and dielectric investigations in laboratory showed no dielectric impact and no partial discharge activity from those gaseous and solid by-products. The manufacturers are continuing their investigations to limit the quantities of various by-products.

After VT inspection and reconditioning, a new ageing tests was launched from March 2018 to August 2021 under the same test voltage as before. During this new period, again, no dielectric event was reported.

4/ Real equipment at site energised since 2018

A first full SF6-free 145 kV/40 kA GIS was energized in 2018 for the utility Axpo Power in Switzerland (Figure 6, example of C4-FN mixture GIS 145kV/40kA)

Composition measurements were performed after 3 years in service (Figure 7). No remarkable deviation was found for the composition of the gas mixture beside the expected measuring uncertainties.

Figure 6: C4-FN mixture GIS, 6 bays of single busbar configuration in the substation Zernez (CH)

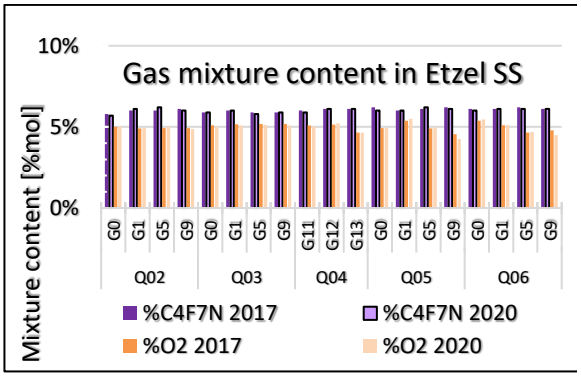

Figure 7 : no deviations for the C4F7N and O_2 concentrations are visible over a service period of three years

Conclusion

C4-FN gas mixture where C4-FN mixed with CO_2 & O_2 is considered as the most promising for High voltage scalability with very low GWP and the best LCA. It has been studied on several aspects (including site conditions) to confirm its long-term stability and will continue to be investigated (see next paper in CIGRE GCC 2022).

[1] V. Hermosillo, C. Gregoire, D. Vancell, J. Ozil, Y. Kieffel, and E. Pierres, 'Performance Evaluation of CO2/Fluoronitrile Mixture at High Short Circuit Current Level in GIS and Dead-Tank High-Voltage Circuit Breakers', A3-301- CIGRE 2018

[2] J. Ozil, F. Biquez, A, Ficheux, Y. Kieffel, L. Drews, R. Luescher, Q. Rognard , '
Return of experience of the SF6-free solution by the use of Fluoronitrile gas mixture and progress on coverage of full range of transmission equipment', A3-117R CIGRE 2021

[3] G. Cyril, D. Ludovic, O. Joël, and L. Diana, '60Hz breaking capability of g3', 6520 MATPOST, 2019.

[4] Cigre Technical Brochure 871 : Current Interruption in SF6-free Switchgear