Despite technological recent progress, withstand voltage of vacuum for large gaps does not increase linearly with gap length. Multiple breaks architectures are needed today to meet ratings at and above 145 kV with vacuum interrupters, increasing consequently length of the product.

Concerning enclosure width, Figure 1 exposes comparison of the needed filling pressure to reach the same dielectric strength as SF6 for both technical air and C4-FN. Technical air pressure within the enclosure should reach a value around 1.2MPa to reach equivalent dielectric strength than SF6 at 0.65MPa. On the other hand, 0.7MPa of technical air corresponds to a SF6-filled enclosure at around 0.25MPa.

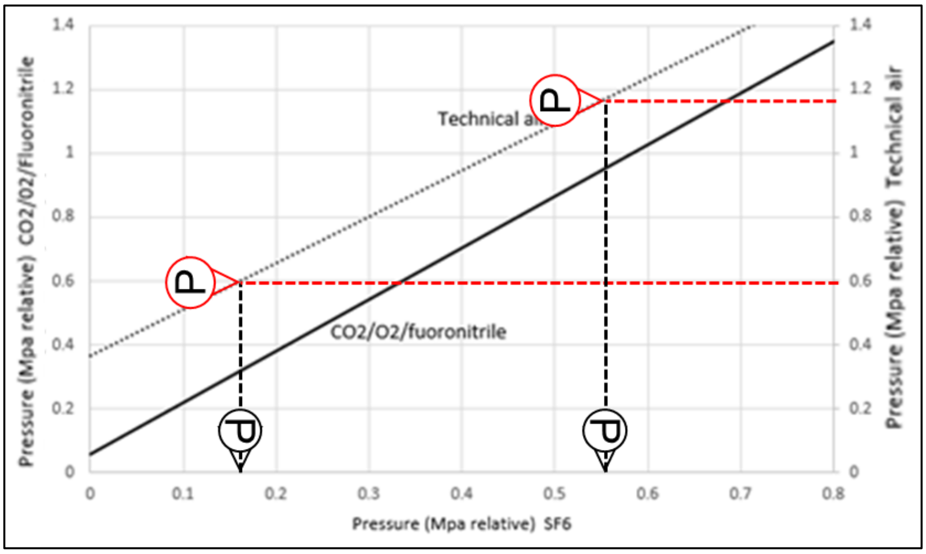

Figure 1: Equivalent pressure for technical air and C4-FN mixture to reach the same dielectric strength as SF_6

Considering this last value of 0.7MPa filling pressure, technical air dielectric strength is around 67% compared to SF_6 one with 0.65MPa filling pressure.

The European Commission is currently co-funding the development of the C4-FN-based 420 kV 63 kA GIS Circuit-breaker under its LIFE Climate action program called LIFEGRID (LIFE18 CCM/FR/001096) aiming at the completion of the 420 kV 63 kA GIS.

LIFEGRID project integrates two 245kV 63kA chambers in series in a double break architecture. Despite a double-break circuit breaker arrangement, the new complete GIS bay based on C4-FN gas mixture offers a similar footprint than its equivalent in SF_6.

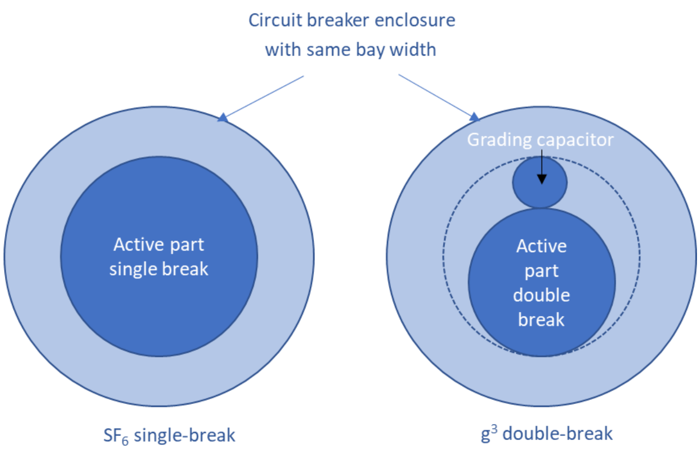

Figure 2: Cross section of the SF_6 (left) and $C4\text{-}FN/O_2/CO_2$ (right) circuit breaker offering the same bay width

Figure 2 shows a cross-section of the circuit-breaker illustrating the compactness of the active part for the double-break to maintain the same outer dimension of the enclosure. 245 kV interrupting unit offers the advantage to be more compact compared to the existing SF_6 single break version. This allows the integration of grading capacitors in the tank with no impact on the bay width.

Even though compartments have the same size as for SF_6, an architecture optimization has been done to keep an equivalent if not lower GIS footprint (depending on the single line diagram selected). This optimization has been studied in several single line diagrams arrangements. Figure 3 shows a simulation of SSEN Kintore substation in Scotland with SF_6 and g^3 products has been made. An equivalent GIS footprint is obtained. This new architecture has been chosen to keep GIS footprint and at the same time a high level of accessibility and ergonomics for operation, maintenance and repair. Drives, gas filling valve, gas monitoring, disconnector/earthing switch viewing windows and control cubicle have been modelled in CAD and their accessibility checked. Coworking with the user has validated this.

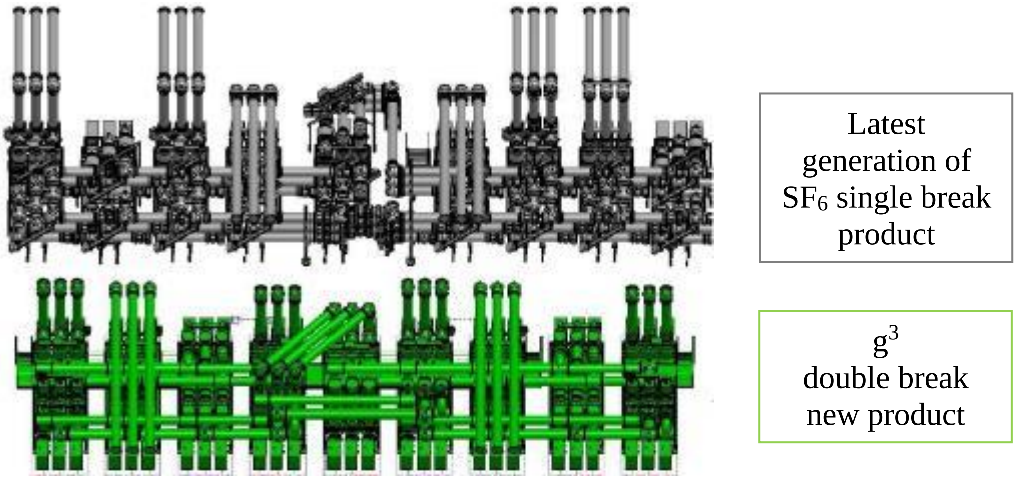

Figure 3: SSEN Kintore substation (Scotland) simulation with SF_6 and g^3 products to the same scale

The following breaking and dielectric tests were performed on the same GIS CB 420kV 63kA 50Hz k_{pp} = 1.3 and 1.5 circuit-breaker prototype using C4-FN-based gas mixture and were fully successful according to IEC 62271-203, IEC 62271-100, and IEC 62271-101 standards:

- T10 / T30 / T60
- T100s / T100a
- L75 / L90
- Capacitive switching LC/CC
- Out of phase OP2
- Dielectric (50Hz / BIL / SIL / BIAS)
- Voltage condition check after breaking

Figure 4 exposes one pole of the circuit-breaker that was subjected to those successfully passed breaking tests.

Figure 4: 420kV GIS circuit-breaker prototype using C4-FN-based gas mixture during breaking test in power laboratory

Those successful results represent a major milestone, paving the way of a complete SF_6 elimination among the grid, and offer a solution scalable at all voltage levels that keeps the same footprint as today HV products.