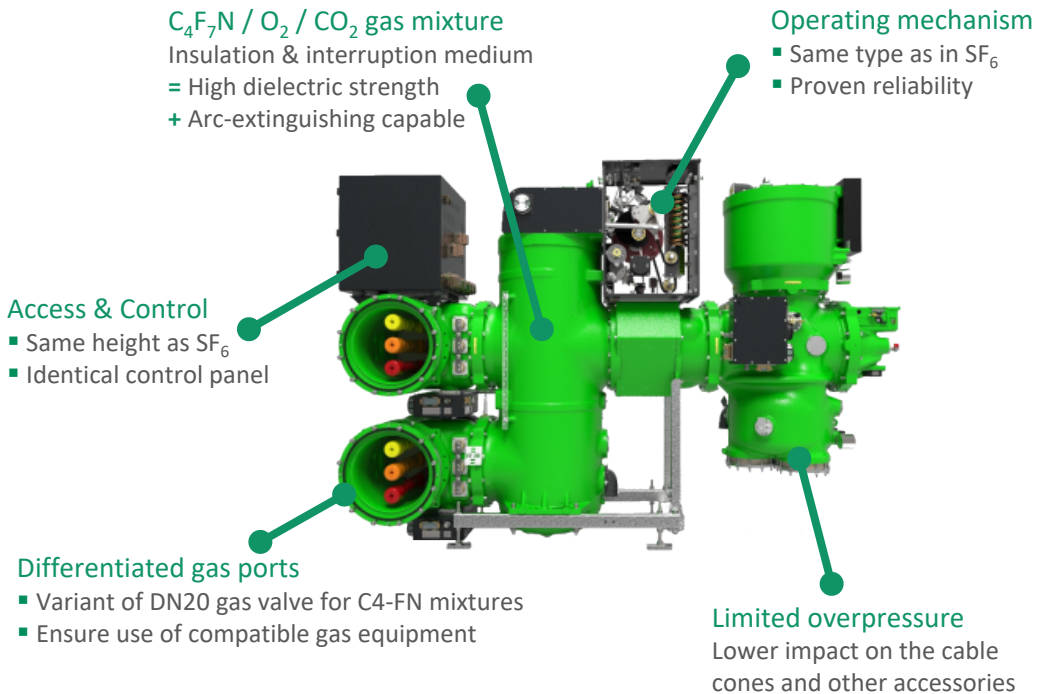


Acting for climate

- IPCC reports are clear: climate change is certain, but we can limit it by immediate global actions
- SF₆ is a high-polluting gas, although SF₆ emissions are only a minor worldwide fraction of GHG
- C4-FN mixtures describe C4-FN (C₄F₇N), O₂ and CO₂ mixtures. This gas has good dielectric and arc-quenching properties that allow a design similar to SF₆ with mostly an increased filling pressure.
- **Several TSOs are already breaking away from SF₆ by choosing SF₆-free solutions**

C4-FN mixtures – Return on experience

Return on experience on a 145kV 40kA GIS installed in 2018 in France



C₄F₇N / O₂ / CO₂ gas mixture
 Insulation & interruption medium
 = High dielectric strength
 + Arc-extinguishing capable

Operating mechanism

- Same type as in SF₆
- Proven reliability

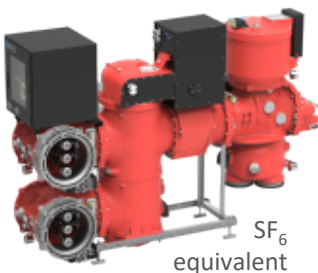
Access & Control

- Same height as SF₆
- Identical control panel

Differentiated gas ports

- Variant of DN20 gas valve for C4-FN mixtures
- Ensure use of compatible gas equipment

Limited overpressure
 Lower impact on the cable cones and other accessories



1:1 in length, width and height
 That's the achievable dimensional footprint of C4-FN solutions compared to state-of-the-art SF₆ ones

Study Committee B3

Substations and Electrical Installations

Paper B3-10672

Return of experience on high voltage equipment in operation using C₄F₇N mixtures

Maxime PERRET, Robert LÜSCHER, Clément COCCHI, Yannick KIEFFEL,
Diana LEGUIZAMON-CABRA, Thomas BERTELOOT

GE Renewable, Grid Solutions

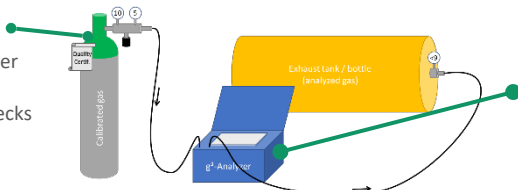
Cross-check of mobile analyzer accuracy

- Comparison of mobile analyzer measurement with high-accuracy pre-mixed gas.
- Simple process with several mixtures tested and analyzed evacuation in another volume.

✓ CO also checked within C₄/O₂/CO₂

Reference gas

- Independent supplier
- Accurate filling
- Multiple GC-MS checks

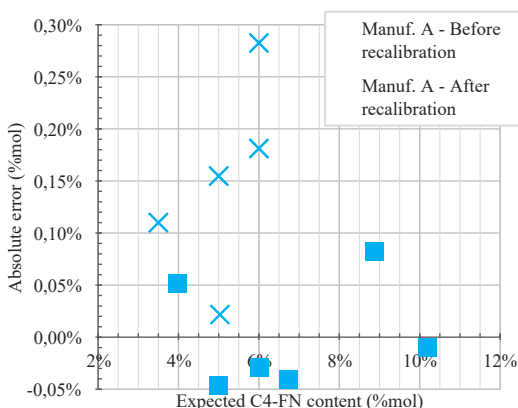


Mobile analyzers

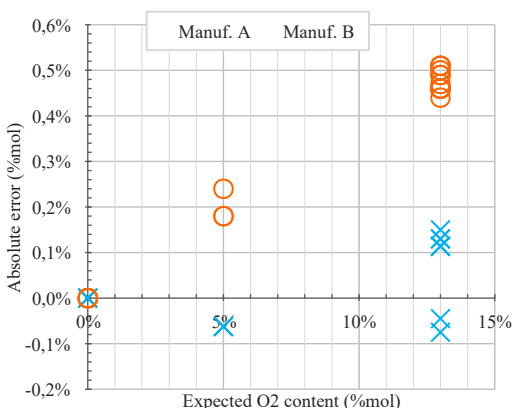
Two known and validated suppliers

- Manufacturer A (Blue square)
- Manufacturer B (Orange circle)

Deviation of C₄-FN measures before and after recalibration



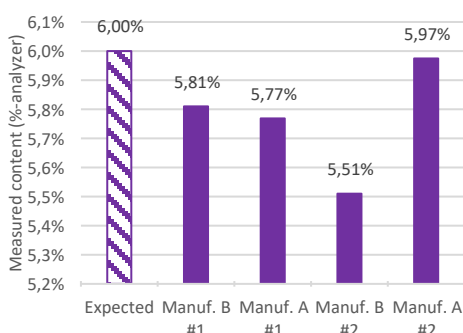
Deviation of O₂ measures



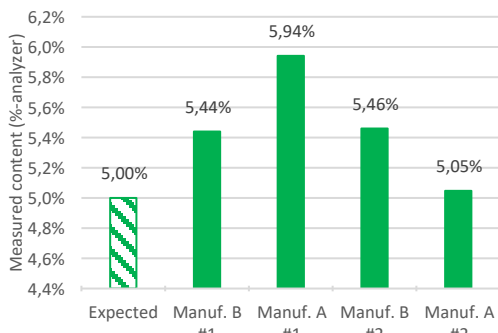
On-site measurement with reference samples

- Application of the above principle: high accuracy known gas (calibrated) is measured by analyzers directly on site
- Very high consistency of measurement before for 2/4 analyzers. Other analyzers not checked.
- Transfer of the calibrated gas in a dedicated bottle was necessary but may have added unknowns.
- Reference gas compatible with the equipment: Pump back of used gas in the equipment in service possible.

C₄-FN measurements of the reference gas



O₂ measurements of the reference gas



Mobile analyzers have demonstrated their capabilities. Frequent calibrations remain necessary. Continuous improvement continuing. New methods can also be implemented

Evolution of the mixture in time

- Several analyzers were used to evaluate the mixture composition.
- Analyzers have a defined tolerance and their accuracy depend on their calibration.
- Some data must be converted from vol-% to mol-%.
- Box & Whisker plots are used to show the statistics of the multiple measures

Legend (one color per device)

- Manuf. A.
- Manuf. B.

C₄-FN content evolution in time

Nov. 2018

Nov. 2020

Apr. 2022

O₂ content evolution in time

