Study Committee A3

Transmission and Distribution Equipment

Paper 10102_2022

SF6-free Solutions for 420 kV Networks using Gas-Insulated Substation (GIS)

Matt BARNETT [1] Bertrand PORTAL [2], Samuel SOUCHAL [2], Quentin ROGNARD [2], Arnaud FICHEUX [2]

[1] SSEN Transmission, United Kingdom, [2] GE Grid Solutions, France

Introduction

- Delivery of net zero brings challenges to the electricity industry beyond generation: transmission asset owners must also consider own CO_2e emission. SF_6 is a key part of this.
- SSEN Transmission have a science-based target that includes tackling SF_6 emissions and a policy to avoid SF_6 wherever technical and commercially viable.

Technical Performance and Reliability

- Environmental case clear, but no technical benefit expected
- Critical to have confidence that SF_6-free has equivalent performance – in both short and long term – as SF_6
- The technical development and testing explained later
- Ratings aligned to requirements
- Change of gas clearly significant but many elements are either not materially affected by this change or the change can easily be handled by during the design and testing process
- Own experience with SF_6 alternatives:

420 kV Development

- Close collaboration and knowledge sharing
- Credible development plan and experience
- Risk mitigations, especially for CB

Operational Issues

- New challenges from different gases / mixtures
- Not to be overlooked but overcome with correct mitigations (some examples to follow)

Overall Selection

- Sufficient confidence to consider SF_6-free GIS as "third option" alongside AIS and SF_6 GIS
- Holistic evaluation: footprint, programme, cost, CO_2e impact, technical risk for project and lifetime etc.

Technical Specification

- Built on IEC standards but address "gaps" and specific needs
- GWP ≤ 1000
- Technical requirements eg
  - cable terminations
  - electrical endurance / gas composition
- Monitoring
- Operational requirements
- Health / EHS
- Not overlook usual requirements from SF_6

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DEVELOPMENT OF 420 KV GIS

Gas selection for the GIS

- 5% mol C_4F_7N / 13% mol O_2 / 82% mol CO_2 mixture is defined for -25°C GIS applications and therefore used for the development of this 420kV SF_6-free GIS.

Development of the GIS bay

- Keep the overall dimensions of the GIS equipment as designed today with SF6 gas.
- Keep high level of accessibility and ergonomics for operation, maintenance and repair
- Performances validated for dielectric, continuous current, capacitive, bus transfer and induced current

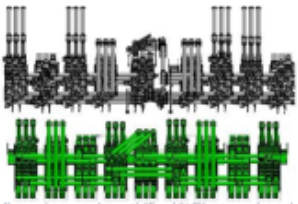


Figure 4-1 – Kintore substation simulation with SF_6 and C4-FN mixture products to the same scale

Figure 4-2 – 420 kV GIS devices during dielectric test (left) and bus transfer test (right)

Development of the GIS circuit-breaker

- Tests done to validate 245 kV 63 kA single-break performances
- Extrapolation of this chamber to be used as 420 kV double-break CB
- Dielectric test already performed on full 420 kV CB
- Test campaign on-going to fully validate the breaking performance on the complete double-break CB

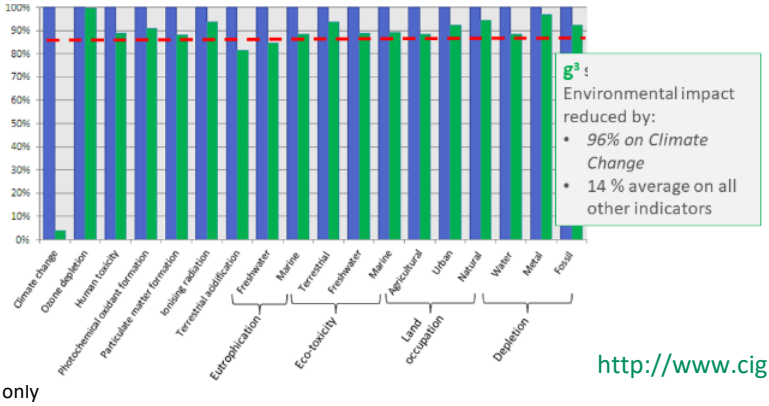
Table 4-1 – Tests performed on CB

	Making	LC/CC	OP2	T10	T30	L75	T100a	T100s
245 kV single-break breaking capability	✓	✓	✓	✓	✓	✓	✓	✓
420 kV double-break breaking capability using grading capacitor	✓	✓	✓	✓	✓	✓	✓	✓

✓	Demonstrated breaking capability
✓	Extrapolation

EHS assessment of the 420 kV GIS solution

- Ful LCA evaluation to assess impact of the complete CO_2e footprint and not just focusing on the gas
- Example of Life Cycle Assessment (LCA) comparison for GIL 420 kV – SF_6 in blue versus C4-FN mixture in green:



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EASE OF GAS HANDLING PROCESS ON SITE

User's expectations

- Unique identification of mixtures and no use of manufactures' brand or trade names
- Explicit labelling with details of the gas or gas mixture used (type, ratio)
- Mandating types of filling point with proposed following table (in discussion within IEC TC 17 committee)
- Always possible to obtain pre-mixed bottles for maintenance / top-up activities

Gas / Gas Mixture	Colour	RAL	Connection
SF_6	Pure Orange	2004	DN8 with M26 thread or DN20 with M45 thread
N_2 / O_2 mixtures	Light Blue	5012	DN20 with M50 thread
Mixtures containing C4-FN (C_4F_7N)	Yellow Green	6018	DN8 with M28 thread or DN20 with M48 thread
Mixtures containing C5-FK ($C_5F_{10}N$)	Telemagenta	4010	DN8 with M24 thread or DN20 with M43 thread
CO_2 / O_2 mixtures	Dusty Grey	7037	Malmquist valve with M32 thread

Manufacturer's solutions

- Use of pre-mixed gases in containers like B50 bottles or C500 container
- Specific SF_6-free gas handling gas carts developed by gas cart manufactures
- Training program in place on the different tools to be used
- Development in progress with gas cart manufacturers of specific QR code and labelling to facilitate site operations