Study Committee A3

Transmission and Distribution Equipment

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SF_6-alternative circuit breaker for 145 kV gas insulated switchgear

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Motivation and summary

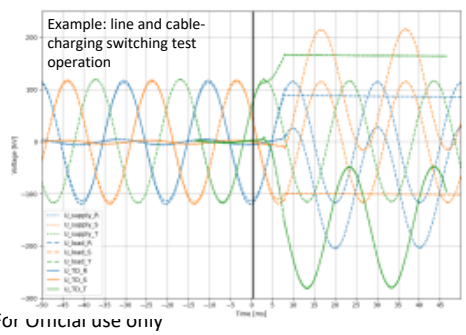
- SF_6-alternative 145 kV / 40 kA / 50 Hz circuit breaker for gas-insulated switchgear (GIS) applications developed using C4-FN, CO_2, and O_2 gas mixture
- Circuit breaker passed all required test duties defined in IEC 62271-100 standard, as well as other relevant tests
- Design changes were made to address differences in thermodynamic and transport properties between CO_2 and SF_6
- Arcing tests under worst-case (or even more severe) conditions demonstrated that nozzle ablation and contact erosion, and not C4-FN decomposition, limit the lifetime of the circuit breaker, as is the case for SF_6 circuit breakers
- Decomposed gas mixture was not classified as toxic, even when considering scenarios with extremely high arc energy input and much smaller volumes than those of the GIS circuit breaker

Design optimization

- C4-FN / CO_2 / O_2 mixture has a higher speed of sound than SF_6, resulting in faster outflow of gas
- Design changes to adapt circuit breaker to gas mixture:
  - Higher filling pressure (6.8 bar_{abs} → 8.8 bar_{abs})
  - Modification of flow cross-sections in the arc zone
  - Modified over-pressure valve setting to increase no-load pressure (cold gas available to cool low current arcs)
  - Special closing mechanism for refilling valve to prevent gas leakage during open operations
- Shields and exhaust adapted for higher gas flow speeds and temperatures

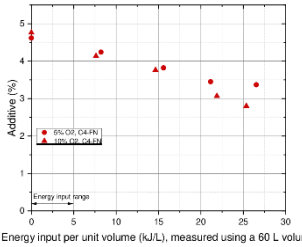
IEC test duties

- IEC temperature-rise test passed for nominal current ratings of 3150 A_{rms} (50 Hz and 60 Hz)
- M2 mechanical test passed after modifications to drive and linkage to accommodate increase in opening speed and no-load pressure build-up
- Low short-circuit current (T10, T30) and out-of-phase test duties benefited from C4-FN, a high dielectric strength additive that also improves the dielectric recovery after arcing
- Modifications were made to accommodate the higher temperatures that result in exhaust region during T100a test (test with maximum short-circuit current)
- All required IEC current interruption test duties passed

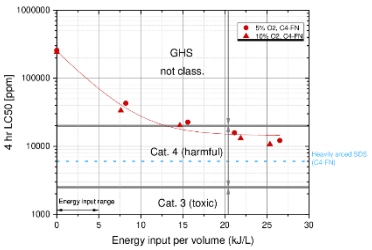


Decomposition of C4-FN does not limit circuit breaker lifetime

- Arc interruption tests performed in a model circuit breaker
- Gas samples collected every 2-3 operations using an automated system and analyzed using GC-MS and FT-IR
- Additive concentration only drops by roughly 0.3 mol% absolute for an input energy of 6 MJ corresponding to twenty 100 % short-circuit current interruptions (15 ms arcing time)



- Toxicity (4 hr LC50) estimated based on concentration of individual decomposition products identified
- For energy input relevant for a GIS circuit breaker, the resulting gas mixture is "not classified" according to GHS (Globally Harmonized System of Classification and Labelling of Chemicals)



Conclusion

- Strong current interruption performance can be achieved using C4-FN / CO_2 / O_2 gas mixtures by making some adjustments to mechanical design and arc zone
- Decomposition of C4-FN does not limit circuit breaker lifetime

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